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13900 N.W. SCIENCE PARK DRIVE • PORTLAND, OREGON 97229

SEPTEMBER 1965
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MODEL

300 PVB®

Instruction Manual

POTENTIOMETRIC VOLTMETER BRIDGE

SERIAL NUMBER: _____

PART NUMBER: 6454

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The following table lists the most recent revision of each page at the present date of printing:

PAGES	DATE
Title	9/65
A	9/65
i	9/65
ii	9/65
1-1 and 1-2	9/65
1-3	7/64
1-4	9/65
1-5 thru 1-7	7/64
2-1 and 2-2	7/64
2-3	9/65
2-4 thru 2-5	7/64
2-6	9/65
2-7	2/65
2-8 thru 2-10	7/64
2-11	10/64
2-12 thru 2-16	7/64
2-17	9/65
2-18 thru 2-22	7/64
2-23 and 2-24	9/65
3-1	7/64
3-2 thru 3-5	9/65
4-1	9/65
4-2 thru 4-6	7/64
4-8 thru 4-13	9/65

TABLE OF CONTENTS

I INTRODUCTION
1.1 DESCRIPTION 1-1
1.2 SPECIFICATIONS 1-2
1.3 APPLICATIONS 1-3

II OPERATION
2.1 GENERAL 2-1
2.1.1 Controls, Connections and Indications 2-1
2.1.2 Battery Life and Battery Check 2-3
2.1.3 Null Balancing 2-4
2.1.4 Meter Interpolation 2-5
2.1.5 Kelvin Klips 2-5
2.2 NORMAL OPERATION 2-7
2.2.1 Voltage Measurement 2-7
2.2.2 Standard Voltage Source 2-8
2.2.3 Current Measurement 2-9
2.2.4 Resistance Measurement 2-11
2.2.5 Ratio Measurement 2-12
2.2.6 Comparison Bridge 2-13
2.3 EXTENDED OPERATION 2-16
2.3.1 External Detector 2-16
2.3.2 External Generator 2-16
2.3.3 External Current Shunt 2-17
2.3.4 External Voltage Dropping Resistor 2-19
2.4 AUXILIARY OPERATION 2-21
2.4.1 Null Detector Auxiliary Operation 2-21
2.4.2 Main Decade Auxiliary Operation 2-21
2.4.3 Internal Resistor Auxiliary Use 2-21
2.5 GENERATOR POWER 2-23

III THEORY
3.1 GENERAL 3-1
3.1.1 The Kelvin Bridge 3-1
3.1.2 The Potentiometric Voltmeter 3-1
3.2 SCHEMATIC DIAGRAMS 3-2

IV MAINTENANCE
4.1 CHECKOUT AND STANDARD CELL CALIBRATION 4-1
4.1.1 Mechanical Checks 4-2
4.1.2 Battery Load Test 4-2
4.1.3 Null Detector Sensitivity Test 4-2
4.1.4 Stability Test 4-3
4.1.5 Main Decade Linearity Test 4-3
4.1.6 Internal Standard Resistor Test 4-4
4.1.7 Standard Cell Calibration 4-4
4.2 TROUBLESHOOTING 4-5
4.2.1 Troubleshooting Table 4-5
4.2.2 Removing the Instrument Case 4-7
4.3 REPLACEMENT PARTS 4-10

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DEKATRAN Decade Transformer

SECTION I

INTRODUCTION

1.1 DESCRIPTION

The ESI Model 300 Potentiometric Voltmeter Bridge is a battery-operated multiple-use dc measurement instrument. It combines in the same case a five-range potentiometric voltmeter, a three-range precision voltage source, an eight-range ammeter, a ten-range Kelvin double bridge for two-, three-, or four-terminal resistance measurements, a four-terminal resistance comparison bridge, a ratiometer, and a high-sensitivity electronic null detector.

Shown in Figure 1.1 are simplified schematic diagrams of the six main functions: potentiometric voltmeter, precision ammeter, standard voltage source, resistance bridge, comparison bridge, and ratiometer.

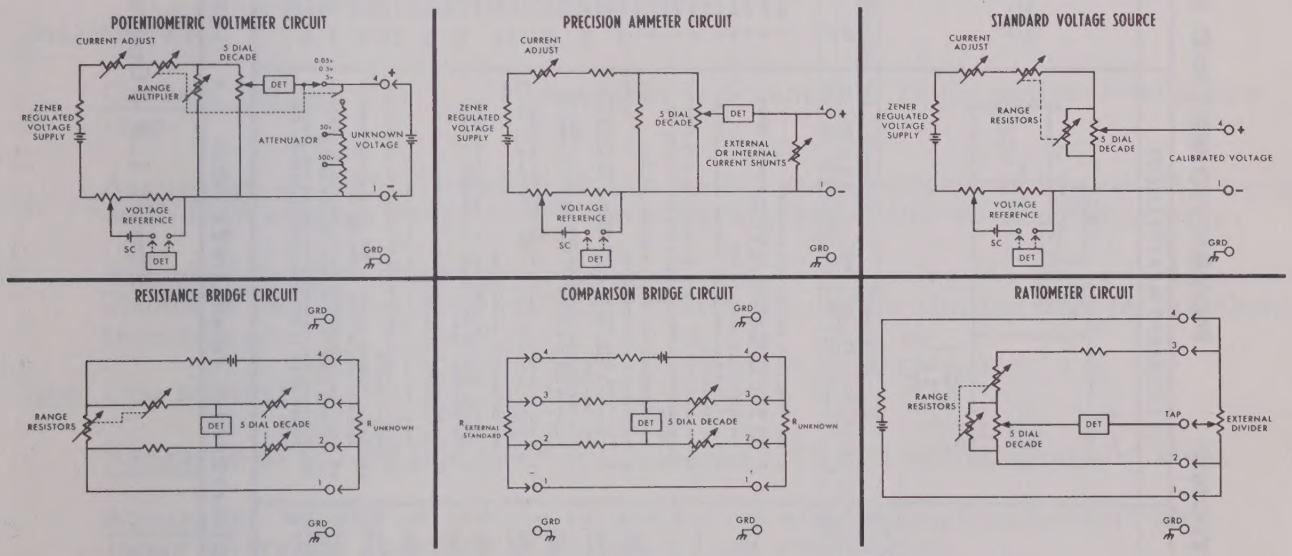
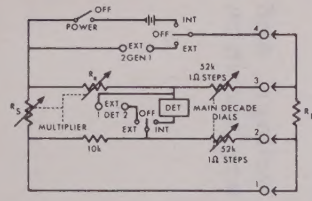


Figure 1.1 - Simplified Schematic Diagrams

Short-form operating instructions for resistance, current, voltage, and ratio measurements are included inside the instrument case and are shown in Figure 1.2.

OPERATING INSTRUCTIONS — POTENTIOMETRIC VOLTMETER-BRIDGE — esi MODEL 300

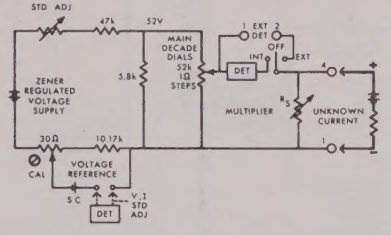
(R) RESISTANCE MEASUREMENT



	OHMS				KILOHMS			MEGOHMS		
MULTIPLIER	X.1	X1	X10	X100	X1	X10	X100	X1	X10	X100
R_S	.1	1	10	100	1	10	100	← 1 →		
R_R	← 10k →							1k	100Ω	

1. Set FUNCTION selector to R position.
2. Set MULTIPLIER selector to .1 OHMS position.
3. Set GENERATOR switch to OFF and DETECTOR switch to OFF.
4. Set MAIN DECADE DIALS to 4. XXXX.
5. Turn POWER switch to ON position; allow 1 minute for stabilization.
6. Set SENSITIVITY control to maximum gain (cw).
7. Connect test resistor to UNKNOWN terminals.
8. Set DETECTOR switch to INT and adjust NULL DETECTOR for zero indication using ZERO control.
9. Turn detector SENSITIVITY control to minimum gain (ccw) and set GENERATOR switch to INT position.
10. Rotate MULTIPLIER knob slowly clockwise, one position at a time, until detector indication reverses polarity.
11. Reduce MAIN DECADE DIAL A setting (ccw) until detector reverses polarity, then rotate one position in opposite direction (cw).
12. Repeat step 11 for dials B thru D, increasing detector sensitivity as required.
13. Make final resistance bridge balance by adjusting dial E for a detector null.
14. Turn GENERATOR switch to OFF position.
15. Recheck null detector zero setting, adjusting ZERO control if necessary.
16. If zero setting has changed, turn GENERATOR switch to INT and rebalance the bridge by adjusting dials D and E as required.
17. The value of the unknown resistor is read from the MAIN DECADE DIAL times the MULTIPLIER setting.
18. Disconnect the unknown resistor and turn POWER switch to OFF position before leaving the Model 300 PVB.

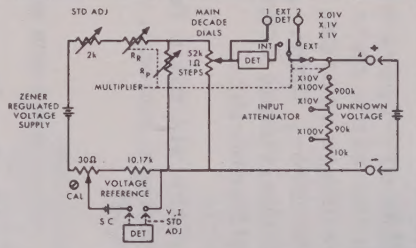
(I) CURRENT MEASUREMENT



	MICROAMPS				MILLIAMPS				AMP
MULTIPLIER	X.1	X1	X10	X100	X1	X10	X100	X1	
R_S	1MEG	100k	10k	1k	100Ω	10Ω	1Ω	.1Ω	

1. Set FUNCTION selector to I position.
2. Set MULTIPLIER selector to desired current range and MAIN DECADE DIALS to 0.0000.
3. Set DETECTOR switch to OFF.
4. Turn POWER switch to ON position; allow 1 minute for stabilization.
5. Set SENSITIVITY control to maximum gain (cw).
6. Adjust ZERO control for NULL DETECTOR zero indication.
7. Turn POWER switch to V, I STD ADJ position.
8. Set DETECTOR switch to INT.
9. Turn STD ADJ rheostat (10 turn) until detector indicates a null; the working voltage reference is now adjusted.
10. Turn DETECTOR switch to OFF position, POWER switch to ON and SENSITIVITY control to minimum gain (ccw).
11. Connect unknown current to UNKNOWN terminals 1 and 4 observing that + polarity connects to terminal 4.
12. Set DETECTOR switch to INT.
13. Increase MAIN DECADE DIAL A (cw) until detector reverses polarity, then rotate one position in opposite direction (ccw).
14. Repeat step 13 for dials B thru D, increasing detector sensitivity as required.
15. Make final null balance using decade dial E.
16. Recheck standardized working voltage by repeating steps 7 and 9.
17. Return POWER switch to ON position and make final null balance using decade dial E.
18. The value of unknown current is read from the MAIN DECADE DIAL times the MULTIPLIER setting.
19. Disconnect the unknown current source and turn the POWER switch to OFF before leaving the Model 300 PVB.

(V) VOLTAGE MEASUREMENT



MULTIPLIER	X.01v	X.1v	X1v	X10v	X100v
R_R	51.7k	47k	← 0 →		
R_P	527Ω	5.8k	← OPEN →		

1. Set FUNCTION selector to V position.
2. Set MULTIPLIER selector to 100 VOLTS position.
3. Set DETECTOR switch to OFF.
4. Set MAIN DECADE DIALS to 4. XXXX.
5. Turn POWER switch to ON position; allow 1 minute for stabilization.
6. Set SENSITIVITY control to maximum gain (cw).
7. Adjust ZERO control for NULL DETECTOR zero indication.
8. Turn POWER switch to V, I STD ADJ position.
9. Set DETECTOR switch to INT.
10. Turn STD ADJ rheostat (10 turn) until detector indicates a null; the working voltage reference is now adjusted.
11. Turn DETECTOR switch to OFF position, POWER switch to ON and SENSITIVITY control to minimum gain (ccw).
12. Connect unknown voltage to UNKNOWN terminals 1 and 4 observing that + end connects to terminal 4.
13. Set DETECTOR switch to INT.
14. Rotate MULTIPLIER knob slowly clockwise, one position at a time until detector indication reverses polarity; return one position in ccw direction.
15. Reduce MAIN DECADE DIAL A setting (ccw) until detector reverses polarity, then rotate one position in opposite direction (cw).
16. Repeat step 15 for dials B thru D, increasing detector sensitivity as required.
17. Make final null balance using main dial E.
18. Recheck the standardized working voltage by repeating steps 8 and 10.
19. Return POWER switch to ON position and make final null balance using decade dial E.
20. The value of unknown voltage is read from the MAIN DECADE DIAL times the MULTIPLIER setting.
21. Disconnect the unknown voltage source and turn the POWER switch to OFF before leaving the Model 300 PVB.

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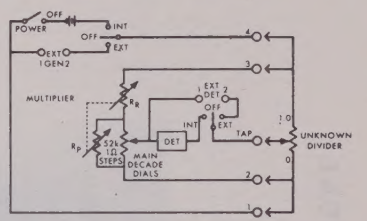
RATIO MEASUREMENT



MULTIPLIER	X.001	X.01	X.1
R_R	99.5k	94.8k	47.8k
R_P	527Ω	5.8k	OPEN

1. Set FUNCTION selector to RATIO position.
2. Set MULTIPLIER selector to .1 RATIO.
3. Set GENERATOR switch to OFF and DETECTOR switch to OFF.
4. Set MAIN DECADE DIALS to 0.0000.
5. Turn POWER switch to ON position; allow 1 minute for stabilization.
6. Set SENSITIVITY control to maximum gain (cw).
7. Connect the unknown resistive voltage divider to the UNKNOWN terminals. If the measurement ratio is between 0 and 0.51, connect the divider high (1.0) end to terminals 3 and 4 and low (0) end to terminals 1 and 2. (If the ratio is between 0.51 and 1.0 reverse the divider high and low end connections.) The divider output terminal connects to the TAP terminal.
8. Set unknown divider to desired output setting.
9. Set the DETECTOR switch to INT and rotate the ZERO control for NULL DETECTOR zero indication.
10. Turn detector SENSITIVITY control to minimum gain (ccw) and set GENERATOR switch to INT.
11. Increase MAIN DECADE DIAL A (cw) until detector reverses polarity, then rotate one position in opposite direction (ccw).
12. Repeat step 11 for dials B thru D increasing detector sensitivity as needed.
13. Make final null balance using decade dial E.
14. The value of the unknown ratio is read from the MAIN DECADE DIAL setting (S) times the MULTIPLIER setting (M). If the divider high and low input leads were reversed because ratio was between 0.51 and 1.0, the ratio equals (1—S)XM.
15. Disconnect the unknown divider and turn the POWER switch to OFF before leaving the Model 300 PVB.

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Figure 1.2 - Operating Instructions

1.2 SPECIFICATIONS

VOLTMETER

Voltage Range: 0 to 511.10 volts in 5 ranges. One microvolt minimum step on lowest range.

Input Resistance: The three ranges from 0 to 5.1110 volts are potentiometric and have infinite input impedance at null. The 51.110 volt and 511.10 volt range have a constant input resistance of 1 megohm.

Accuracy: ±0.02% of reading or one switch step, whichever is greater.

VOLTAGE SOURCE

Voltage Range: 0 to 5.1110 volts in 3 ranges. One microvolt minimum step on lowest range.

Accuracy: Under no-load conditions, ±0.02% of reading or one switch step, whichever is greater.

Working Voltage: Zener regulated mercury battery.

Reference Voltage: A portable thermally lagged unsaturated standard cell.

AMMETER

Current Range: 0 to 5.1110 amperes in 8 ranges. 10 picoampere minimum step.

Accuracy: ±0.02% of reading or one switch step, whichever is greater, except on 5.1110 ampere range where the accuracy is ±0.06% or one switch step.

Extended Range: Multiplier setting A permits extending the range by external shunts to very small or very large values of current limited only by the shunts themselves.

KELVIN BRIDGE

Range: 0 to 511.10 megohms in 10 ranges. 10 microhms minimum step.

Accuracy: ±0.02% of reading or one switch step, except on 0.51110 ohm range where the accuracy is ±0.06% or one switch step.

COMPARISON BRIDGE

Range: 0 to 511.10% of nominal reading of 1.0000.

Accuracy: 0.01% of reading or one switch step, whichever is greater.

RATIOMETER

Range: 0 to .51110 in three ranges.

Accuracy: 0.01% of reading or one switch step, whichever is greater.

NULL DETECTOR

Minimum Detectable Signal: Less than 5 microvolts.

Input Resistance: Approximately 1 megohm.

Zero Stability: ± 5 microvolts.

AC Rejection: At least 70 db at 50 cps improving at higher frequencies.

Sensitivity: Continuously variable control provides attenuation of approximat 80 db from minimum detectable signal level without affecting damping respor or zero adjustment.

Zero Suppression: Zero suppression control provides up to ±200 microvolts to offset externally produced thermal voltages.

Overload Protection: Up to 600 volts across the input terminals at any sensitivity setting will cause no damage.

Overload Recovery Time: Full scale deflection recovery within three secon Recovery within five seconds for overloads of 10,000 times minimum detectable signal. Recovery within 60 seconds for overloads 100 million times minimum detectable signal (500 volts).

Source Impedance: No zero drift or damping response change from short-circuit to open-circuit conditions.

Stabilization Time: Sixty seconds or less after switching on batteries.

Detector Guarding: Detector and battery power supply mounted on separate metal guard chassis maintain at least 10^{11} ohms from either terminal to ground. Either or both terminals may be driven to at least 600 volts above case ground.

Solid State Amplifiers: Only silicon diodes, silicon transistors, tantalum capacitors and similar high-quality components used for long circuit life.

Power Consumption: Approximately 30 milliwatts.

POTENTIOMETRIC VOLTAGE STABILITY

Reference Voltage: A portable miniature unsaturated standard cell is the reliable standard of voltage to +0.01% and capable of thirty-day stability of ±0.001%.

Working Voltage: Zener regulated mercury battery.

POWER SUPPLY

Battery Type: Five 1.5-volt "D" cells, two 8.4-volt mercury batteries, E286 or equivalent.

Battery Life: Approximately 2000 hours of normal use.

PHYSICAL DIMENSIONS

Length:	36.8 cm (14.5 in.)
Width:	28.7 cm (11.3 in.)
Height:	18.3 cm (7.2 in.)
Weight:	8.2 kg (18 lbs)

TEMPERATURE LIMITS

The temperature limits are the limits of the unsaturated cell that is used as the voltage reference.

Storage Temperature: -35°F to +160°F (-37°C to +70°C)

Operating Temperature: +40°F to +140°F (+5°C to +60°C)

1.3 APPLICATIONS

It is not possible to enumerate all the possible applications of an instrument that is as versatile as the Model 300 PVB. The Model 300 is as portable and as rugg as a multimeter, and as accurate as many standard laboratory instruments. It may be used whenever and wherever dc measurements are required. We have listed a few of the applications that have occurred to us, but this is by no means a complete list. From time to time we will publish bulletins concerning applications. If you have an unusual or interesting application, or if you have a question about some use of the instrument, let us know. Write to: Technical Services, Electro Scientific Industries, 13900 N. W. Science Park Drive, Portland, Oregon 97229.

1.3.1 As a voltmeter the Model 300 PVB is useful for potentiometric temperature measurement with base or noble metal thermocouples, measurement of high impedance electrochemical voltages, such as pH and Redox, monitoring of voltage transients and drifts in industrial process controls, and precision electronic circuit voltage measurements.

1.3.2 As a voltage source the Model 300 PVB may be used for direct calibration of potentiometric recorder controllers, X - Y recorders, high impedance voltmeters, and similar devices.

1.3.3 As a precision voltage divider and ratiometer the Model 300 PVB permits the direct calibration of decade voltage dividers and volt boxes. It will make linearity tests of all types of resistive slidewires and precision potentiometers.

1.3.4 As an ammeter the Model 300 PVB is useful for the calibration of standard ammeters, milliammeters, and micro-ammeters, as well as standard voltmeters, millivoltmeters, and microvoltmeters. It can measure currents in Hall effect and photosensitive devices, reverse currents in diodes and transistors, currents in reactor monitoring and control systems, and calibrate constant current power supplies.

1.3.5 As a Kelvin bridge the Model 300 PVB is capable of two-, three-, and four-terminal measurements. It is very useful for four-terminal measurements of the resistance of switch and relay contacts, carbon brushes, connectors, fuses, squibs, printed circuits, wires, rods, cables, and grounding systems. Also it can be used for precision resistance thermometry, strain gauge calibration, three-terminal measurements of high value resistors, high resistance solid state devices, and precision phototube load resistance.

1.3.6 As a comparison bridge the Model 300 PVB makes direct-reading comparisons of a two-, three-, or four-terminal reference device and the resistance of an unknown device. The four terminals make it possible to make accurate comparisons of resistors or transducers remote from the instrument in environmental test chambers or industrial control equipment.

1.3.7 With battery operation and guarded null detector the Model 300 PVB is ideal as a floating differential voltmeter for critical measurements where both terminals of the instrument must be above ground. A reference standard high voltage power supply can be converted into a high voltage potentiometric voltmeter with the 300 PVB providing a guarded null detector

and a five-digit calibrated vernier voltage down to 1 microvolt per step which may be added to the reading of the reference supply. This makes it possible to monitor very small drifts and transients in regulated power supplies, high voltage zener diodes, and similar highly-regulated voltage sources.

SECTION II

OPERATION

2.1 GENERAL

The ESI Model 300 PVB is a battery-operated multiple-use dc measurement system. Operation of the instrument is similar to the operation of many other bridge and potentiometer instruments. Since the instrument is extremely flexible, there are many modes of operation. As a matter of fact, one might suspect that there are as many modes of operation as there are users. The various modes of operation of the instrument have been categorized as normal, extended and auxiliary.

Normal operation is operation as a resistance bridge, a potentiometric voltmeter, a precision ammeter, standard voltage source, a comparison bridge, or a ratio bridge. In general, normal operation is the use of the instrument to make measurements within the specified range and without external equipment.

Extended operation is operation with external equipment to extend the range, sensitivity or resolution of the instrument; for example, operation with external voltage dropping resistors or external current shunts to increase the range of voltage and current measurement.

Auxiliary operation is operation of only part of the instrument; for example, using the null detector alone, or using the main decades as a resistive voltage divider.

2.1.1 Controls, Connections, and Indications

The controls and connections necessary to operate the Model 300 PVB are illustrated in Figure 2.1. A brief description of each control and connection follows:

The main decade dials are the null balancing controls and provide a five-digit in-line readout. The X position on each dial except the first provides a ten percent range overlap. All dials except the first may be continuously rotated.

The NULL DETECTOR meter provides an indication of bridge or potentiometric null and may be used in most measurement applications for interpolation of one digit more than provided by the five-digit decade dials.

ZERO control permits balancing of externally generated thermal voltages.

SENSITIVITY control provides continuous control of null detector sensitivity to a maximum of a few microvolts.

POWER switch turns all battery circuits on and off, connects the internal standard cell for voltage and current standardization, and connects internal batteries to the NULL DETECTOR meter for battery voltage checks.

V, I STD ADJ control is a ten-turn rheostat that provides adjustment of the zener-regulated supply so that the supply voltage may be calibrated against the internal standard cell.

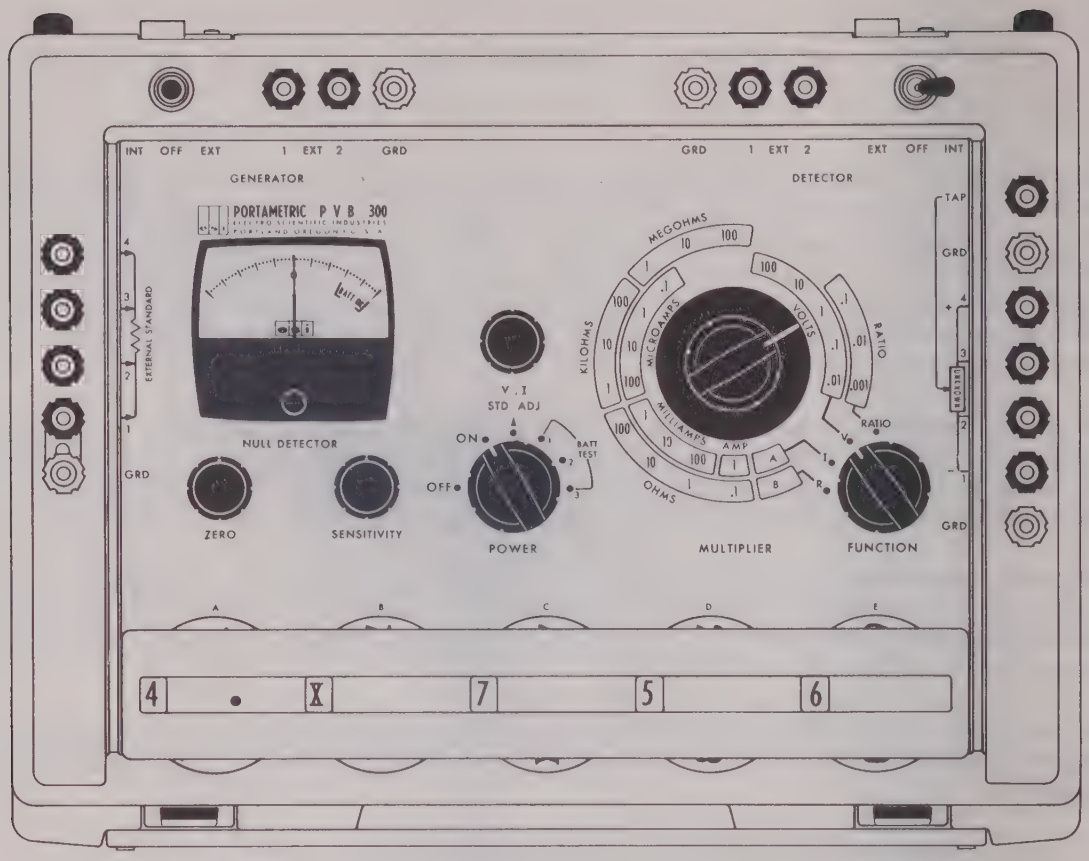


Figure 2.1 - Controls and Connections

MULTIPLIER switch selects the range multiplier for each basic function of the instrument, and has a switch position for switching in an external standard or external current shunt.

FUNCTION switch selects one of the four basic circuit configurations: a potentiometric voltmeter, ratiometer, ammeter, or a Kelvin resistance bridge.

GENERATOR switch applies an internal or external power source to the resistance bridge or ratiometer.

DETECTOR switch connects either the internal or an external detector to the bridge or potentiometric circuit.

Gold-plated GRD binding posts are all connected to the instrument case. The GRD connectors are provided in positions near binding posts that are often required to be at ground potential. A gold-plated shorting link is provided to connect the external connecting terminals to the GRD binding posts.

EXTERNAL STANDARD terminals provide connection points for an external standard resistor for comparison bridge operation, and for external current shunts for measurement of currents greater than 5 amperes.

EXT GENERATOR terminals provide connection points for an external power source for special measurements.

EXT DETECTOR terminals provide connection points for an external detector. EXT DETECTOR terminal 1 may also be used as the output terminal of the instrument when it is used as a standard voltage source.

TAP terminal is used to connect the center point of ratio devices for ratio measurement.

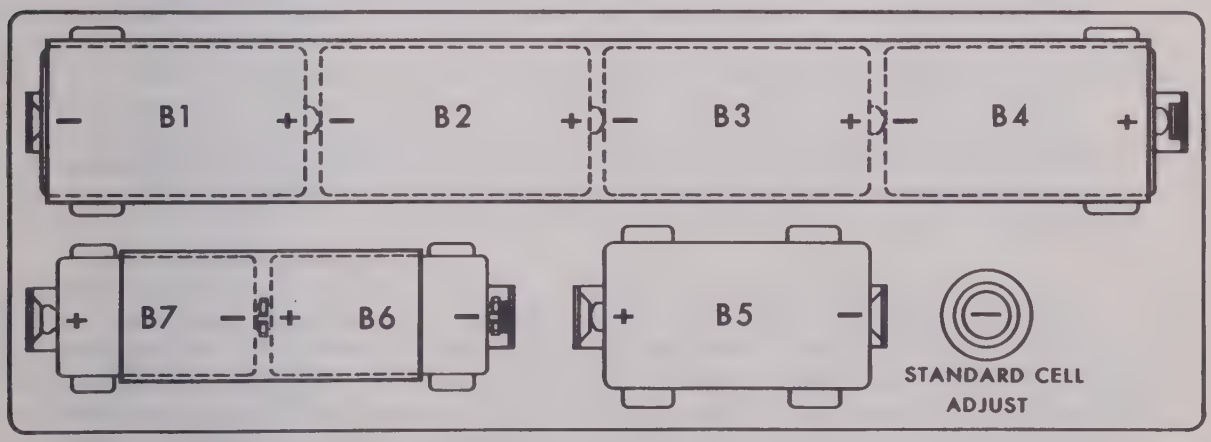
UNKNOWN terminals provide connection points for unknown voltage, current or resistance. Four UNKNOWN terminals are provided for four-terminal resistance measurement. Normally shielded test leads with KELVIN KLIPS® are connected to the UNKNOWN terminals.

2.1.2 Battery Life and Battery Check

The normal life of the batteries is approximately 2000 hours. This is approximately one year at forty hours a week. The POWER switch turns all battery circuits on and off and provides a means of checking the batteries.

To check the batteries, turn the POWER switch to BATT TEST positions 1, 2 and 3 in turn. If the batteries are good, the NULL DETECTOR pointer will be in the BATT OK range. The batteries should be checked every day that the instrument is used.

If a battery check shows one of the batteries to be weak, it should be replaced. To replace batteries, remove the battery compartment cover which is held in place by two screws. Battery locations and types are shown in Figure 2.2 and inside the battery compartment cover.



B1 THROUGH B5 ARE 1.5V 'D' CELL EVEREADY D99 OR EQUIVALENT.
B6 AND B7 ARE 8.4V MERCURY BATTERY EVEREADY E286 OR EQUIVALENT.
NOTE: 9V TRANSISTOR BATTERIES E226 CAN BE SUBSTITUTED FOR MERCURY BATTERIES, BUT WITH REDUCED LIFE.

Figure 2.2 - Battery Locations

BATT TEST position 1 of the POWER switch, tests the four alkaline cells B1 through B4. BATT TEST position 2 tests the two mercury batteries B6 and B7 in series with the single cell B5. If cell B5 is not in the battery

clips, there will be no indication on the NULL DETECTOR when the POWER switch is in BATT TEST position 2, but normally, a low indication for BATT TEST position 2 indicates that the two mercury batteries are weak. BATT TEST position 3 tests the 1.5-volt cell B5.

2.1.3 Null Balancing

Most of the measurements that are made with the Model 300 PVB are of the sort that require balancing a bridge. Here are a few hints to assist the user in finding a null.

No damage will be done to the instrument by leaving the SENSITIVITY control at maximum (fully clockwise) and seeking a null. Usually the NULL DETECTOR pointer snaps from one end of full scale to the other when the setting of the first two or three main decade dials is turned past the balancing point. But when one is seeking a first approximation to a null, it is better to decrease the sensitivity of the detector so that the pointer indicates something less than full scale. As the setting of each of the main decade dials approximates the balance point, (one dial division before the detector indicates a reversed polarity), the sensitivity should be increased so that the NULL DETECTOR indicates something less than full scale again. Then proceed with the next decade dial.

Another advantage of decreasing the sensitivity is that it makes searching for an unknown value easier. If the pointer approaches zero when you turn one of the main decade dials, you know that you are going in the right direction.

The step-by-step operation instructions must be written with the assumption of the worst case, (i.e., that the range and the value of the unknown are completely unknown). For this reason, the operating instructions describe a process that searches through all ranges and values for a null. In most cases, this is not necessary. The approximate value of the unknown is usually known. If you have some idea of the value of the unknown, set the MULTIPLIER and the first main decade dial to the approximate value of the unknown, and then proceed according to the step-by-step instructions.

The main decade dials, except for the first, can be rotated through a full circle. There are eleven positions marked on each of these four switches, of which the eleventh position is marked X. The X position corresponds to 1 on the next higher switch. That is, 1.998X is equal to 1.9990, and 1.0000 is equal to 0.X000, 0.9X00, 0.99X0 and 0.999X. This feature is quite useful when one is measuring quantities near the integer points. As an example, suppose that it is necessary to measure a set of resistors that are nominally 100 ohms. If the MULTIPLIER dial is set to 100 OHMS, and the main decade dials are set to 0.999X, then the measurement is exactly 100 ohms. If the dials are set to 0.99X3, the measurement is 100.03 ohms, and if the dials are set to 0.9997, the measurement is 0.03 ohms less than 100 ohms. Notice that it is only necessary to move the last two dials when the measurement is changed from 100.03 ohms to 99.97 ohms. A change of measurement of this sort can be quite frustrating on an instrument that has only ten positions, because all five dials have to be changed. It is even worse when the dials cannot be turned directly from 9 to 0, but have to be turned from 9 to 8 to 7 and around to 0.

2.1.4 Meter Interpolation

In many measurement applications, it is possible to interpolate with the NULL DETECTOR indication. Usually it is not possible to get an exact null indication with the main decade dials, but the null will lie between switch steps of main decade dial E. the NULL DETECTOR indication will be to the left of zero on one dial setting, and to the right of zero one switch step away. To use the NULL DETECTOR indication for interpolation, use the following procedure:

(1) Obtain the nearest approach to a null that is possible. Complete instructions are in Section 2.2

(2) Note the NULL DETECTOR indication for the two adjacent switch steps of main decade dial E that are nearest to the null. The indications will be on each side of zero.

(3) Let M be the NULL DETECTOR indication when main decade dial E is on the lower of the two adjacent switch steps, and let N be the NULL DETECTOR indication for the higher switch step. Add the following interpolation fraction to the lower of the two switch steps:

$$\frac{M}{M + N}$$

For example: The voltage of a dry cell is measured. When the main decade dials are set to 1.4872, the NULL DETECTOR pointer is 8 dots from zero, when the main decade dials are set to 1.4873, the NULL DETECTOR pointer is 5 dots on the other side of zero. The interpolation fraction is:

$$\frac{8}{5 + 8} = \frac{8}{13}$$

Since 8/13 is approximately equal to 0.6, the interpolated main decade dial reading is 1.48726.

2.1.5 Kelvin Klips®

The Model 300 PVB is supplied with Kelvin Klips which make four-terminal connections to resistances that are to be measured. The Kelvin Klips can be used for current, voltage, and ratio measurements as well as resistance measurements. There is one exception to the universal use of the Kelvin Klip, and one precaution in their use.

The exception is measurement of a four-terminal resistor that has an internal junction, such as the Thomas-type precision resistor. Each of the four internal leads in this type resistor has a resistance of about one milliohm. Measurement with Kelvin Klips will result in about a two-milliohm error. Use four separate test leads to avoid this error. See Figure 2.3 for connections.

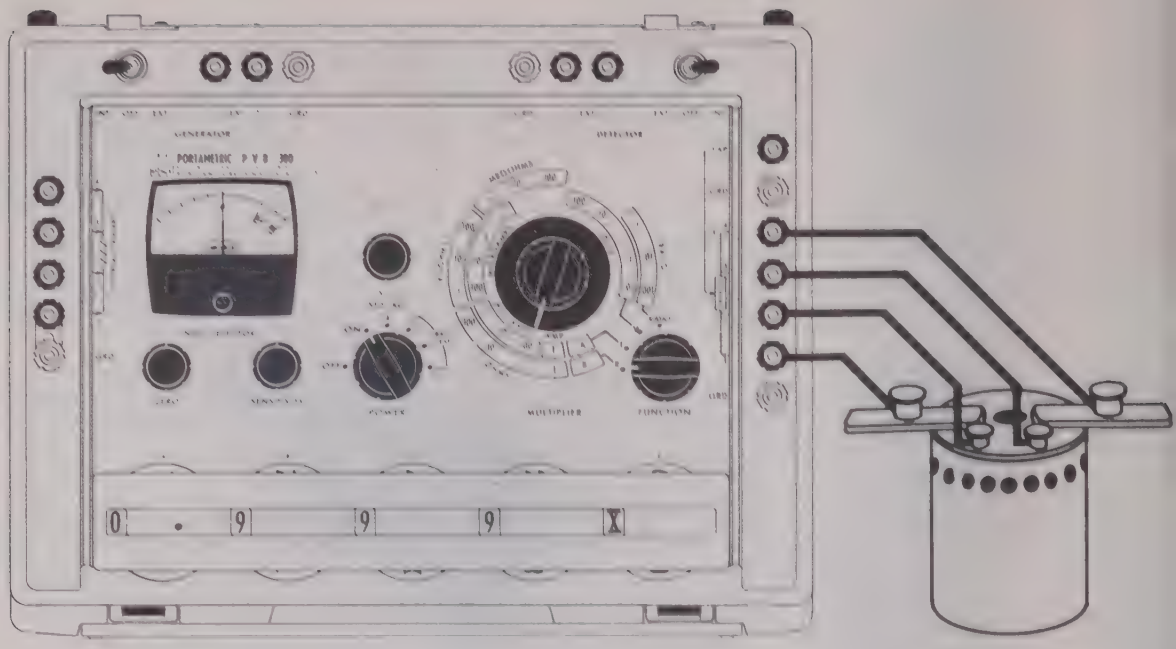


Figure 2.3 - Four-Terminal Resistor Connection

The precaution in using Kelvin Klips is: make sure that both jaws make contact with the same electrical conductor. Printed or etched circuits are sometimes difficult to connect with Kelvin Klips.

The occasions on which there may be some difficulty with Kelvin Klips are quite rare. The recommended technique is to connect the Kelvin Klips to the Model 300 PVB, and use them for all measurements except measurement of precision four-terminal resistors.

Different types of Kelvin Klip assemblies are furnished with the Model 300 PVB, differing mainly in the assembly that connects to the UNKNOWN terminals. Those illustrated in this manual are typical. The table of replacement parts, (paragraph 4.3), lists all available types of Kelvin Klips.

2.2 NORMAL OPERATION

Normal operation of the Model 300 PVB is operation as a precision potentiometric voltmeter or as a Kelvin resistance bridge. Paragraphs 2.2.1 through 2.2.3 describe operation of the instrument as a precision potentiometric voltmeter; Paragraph 2.2.1 describes voltage measurement, Paragraph 2.2.2 describes operation as a standard voltage source, and Paragraph 2.2.3 describes current measurement. Paragraphs 2.2.4 through 2.2.6 describe operation as a Kelvin resistance bridge; Paragraph 2.2.4 describes resistance measurement, Paragraph 2.2.5 describes ratio measurement, and Paragraph 2.2.6 describes operation as a comparison bridge.

2.2.1 Voltage Measurement

CAUTION

Make sure that FUNCTION switch is in V position before measuring voltages. Voltage sources capable of delivering power in excess of one watt could damage current shunts or bridge elements if FUNCTION switch is in I, R or RATIO positions.

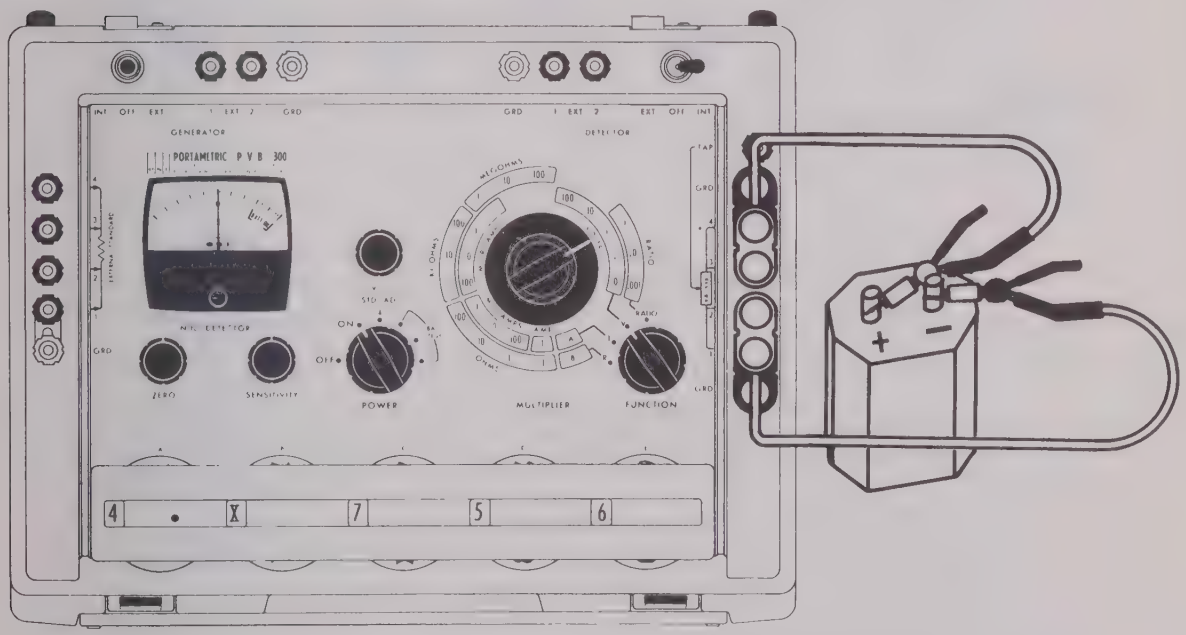


Figure 2.4 - Voltage Measurement

1) Set FUNCTION selector to V position.
2) Set MULTIPLIER selector to 100 VOLTS position.
3) Set DETECTOR switch to OFF.
4) Set MAIN DECADE dials to 4.XXXX.
5) Turn POWER switch to ON position; allow 1 minute for stabilization.
6) Set SENSITIVITY control to maximum gain (cw).
7) Adjust ZERO control for NULL DETECTOR zero indication.
8) Turn POWER switch to V, I STD ADJ position.
9) Set DETECTOR switch to INT.

10) Turn STD ADJ rheostat (10 turns) until detector indicates a null; working voltage reference is now adjusted.
11) Turn DETECTOR switch to OFF position, POWER switch to ON and SENSITIVITY control to minimum gain (ccw).
12) Connect unknown voltage to UNKNOWN terminals 1 and 4 observing that + end connects to terminal 4. Kelvin Klips® can be used. (See Figure 2.4)
13) Set DETECTOR switch to INT.
14) Rotate MULTIPLIER knob slowly clockwise, one position at a time until detector indication reverses polarity; return one position in ccw direction.
15) Reduce MAIN DECADE dial A setting (ccw) until detector reverses polarity, then rotate one position in opposite direction (cw).
16) Repeat step 15 for dials B thru D, increasing detector sensitivity as required.
17) Make final null balance using main dial E.
18) Recheck the standardized working voltage by repeating steps 8 and 10.
19) Return POWER switch to ON position and make final null balance using decade dial E.
20) The value of unknown voltage is read from the MAIN DECADE dial times the MULTIPLIER setting.
21) Disconnect the unknown voltage source and turn the POWER switch to OFF before leaving the Model 300 PVB.

2.2.2 Standard Voltage Source

CAUTION

Do not connect a standard voltage supply to another voltage source. Do not leave the instrument set as a standard voltage source so that some other person might inadvertently connect it to a voltage source. Setting the Model 300 PVB as a standard voltage source places precision resistors of the main decade across the output. Even low voltages may damage the decade resistors with the dials in certain positions.

NOTE: The standard voltage source is intended as a no-load supply. If current is drawn from the standard voltage source, the accuracy will decrease.

1) Set FUNCTION switch to V.
2) Set MULTIPLIER to 1 VOLT.
3) Set MAIN DECADE dial to 0.0000.
4) Set DETECTOR and GENERATOR switches to OFF position.
5) Turn the POWER switch to ON position and allow one minute for stabilization.
6) Set SENSITIVITY control for maximum gain (cw) and balance NULL DETECTOR for a zero null with ZERO control.
7) Turn the POWER switch to V, I STD ADJ and set DETECTOR switch to INT. Balance NULL DETECTOR with STD ADJ control. The working voltage reference is now adjusted.
8) Set DETECTOR to OFF position and POWER switch to ON position.

9) Set MULTIPLIER switch to 1, .1, or .01 as appropriate.
10) Set MAIN DECADE dials to the desired voltage. The output voltage will be the MAIN DECADE dial setting times the MULTIPLIER setting.
11) Connect a test lead between EXT DETECTOR terminals 1 and 2. The output voltage positive terminal is UNKNOWN terminal 4, and the negative terminal is UNKNOWN terminal 1. Connect outputs as required, Kelvin Klips can be used. See Figure 2.5 for connections.

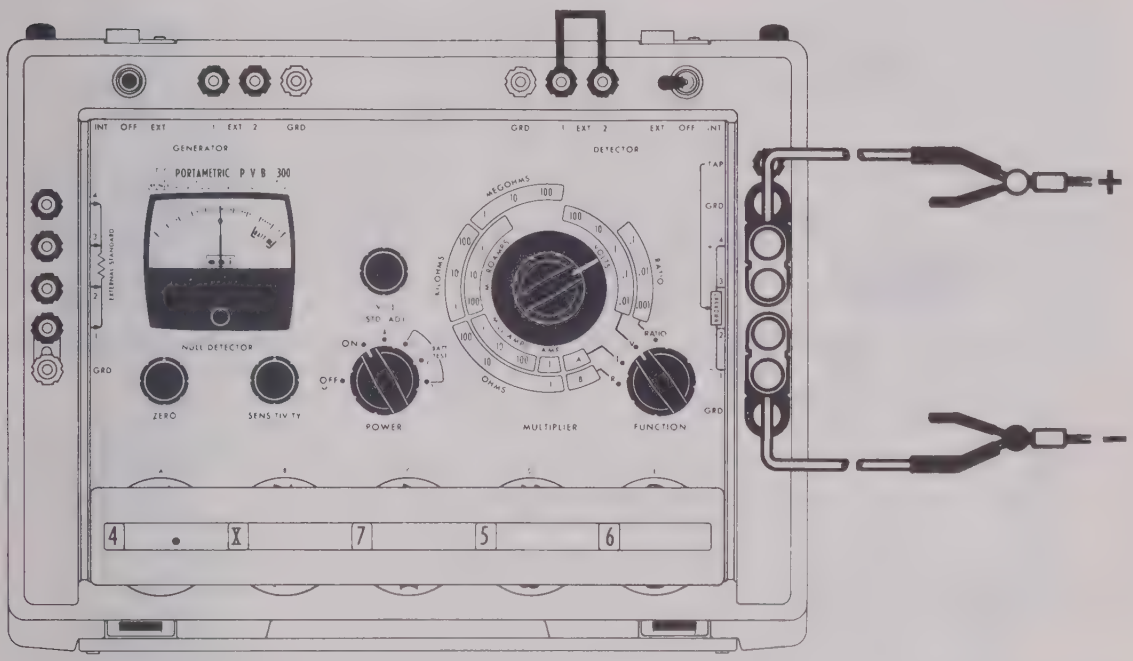


Figure 2.5 - Standard Voltage Source

12) Set DETECTOR switch to EXT position to apply voltage.
13) Disconnect outputs and turn POWER switch to OFF before leaving the Model 300 PVB.

2.2.3 Current Measurement

CAUTION

Protect the precision current shunts. Do not allow the power dissipated by the current shunts to be more than one watt, (5 watts on 1 amp multiplier setting). Determine the range of current to be measured before connecting the Model 300 PVB. The power dissipated by the shunts may be calculated from the shunt resistances listed in the following table:

	MICROAMPS				MILLIAMPS			AMP
MULTIPLIER	X1	X1	X10	X100	X1	X10	X100	X1
R_s	1 MEG	100k	10k	1k	100Ω	10Ω	1Ω	.1Ω

NOTE: Maximum voltage drop for full-scale current is 0.51110 volts for all ranges.

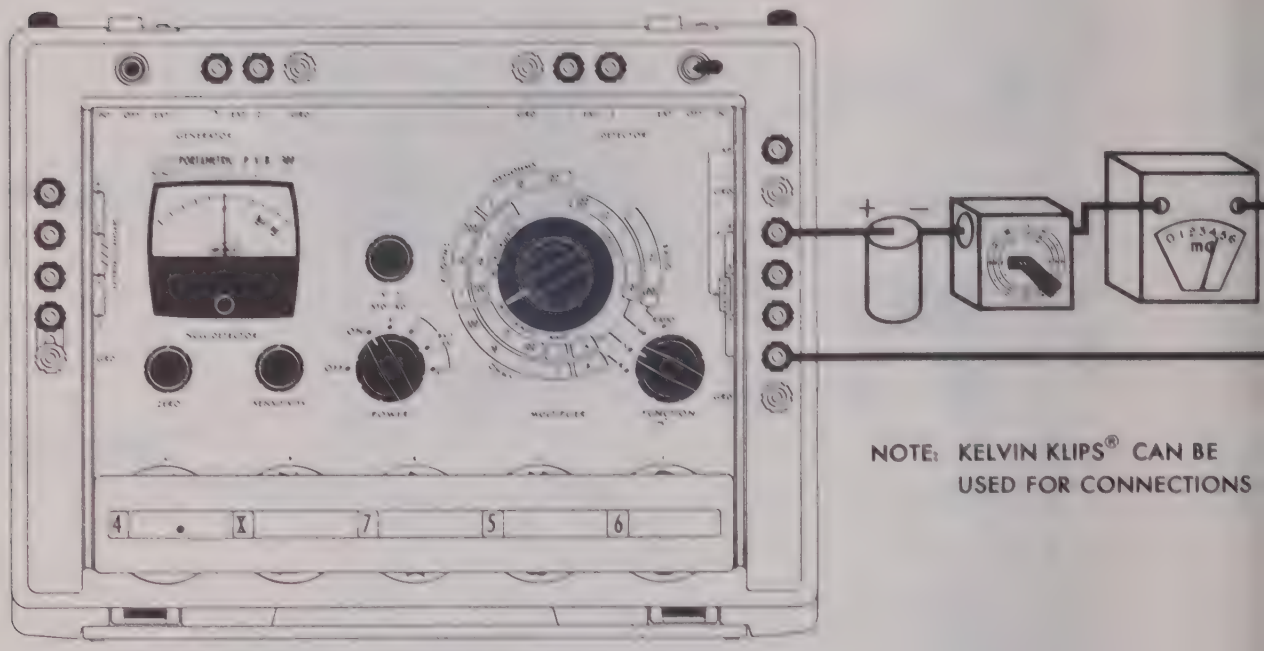


Figure 2.6 - Current Measurement

1) Set FUNCTION selector to I position.
2) Set MULTIPLIER selector to desired current range and MAIN DECADE dials to 0.0000.
3) Set DETECTOR switch to OFF.
4) Turn POWER switch to ON position; allow 1 minute for stabilization.
5) Set SENSITIVITY control to maximum gain (cw).
6) Adjust ZERO control for NULL DETECTOR zero indication.
7) Turn POWER switch to V, I STD ADJ position.
8) Set DETECTOR switch to INT.
9) Turn STD ADJ rheostat (10 turns) until detector indicates a null; the working voltage reference is now adjusted.
10) Turn DETECTOR switch to OFF position, POWER switch to ON and SENSITIVITY control to minimum gain (ccw).
11) Connect unknown current to UNKNOWN terminals 1 and 4 observing that + polarity connects to terminal 4. Kelvin Klips can be used. See Figure 2.6.
12) Set DETECTOR switch to INT.
13) Increase MAIN DECADE dial A (cw) until detector reverses polarity, then rotate one position in opposite direction (ccw).

14) Repeat step 13 for dials B thru D, increasing detector sensitivity as required.
15) Make final null balance using decade dial E.
16) Recheck standardized working voltage by repeating steps 7 and 9.
17) Return POWER switch to ON position and make final null balance using decade dial E.
18) The value of unknown current is read from the MAIN DECADE dial times the MULTIPLIER setting.
19) Disconnect the test leads and turn the POWER switch to OFF before leaving the Model 300 PVB.

2.2.4 Resistance Measurement

1) Set FUNCTION selector to R position.
2) Set MULTIPLIER selector to .1 OHMS position.
3) Set GENERATOR switch to OFF and DETECTOR switch to OFF.
4) Set MAIN DECADE dials to 4.XXXX.
5) Turn POWER switch to ON position; allow one minute for stabilization.
6) Set SENSITIVITY control to maximum gain (cw).
7) Connect test resistor to UNKNOWN terminals. See Figures 2.7 and 2.8 for connections.
8) Set DETECTOR switch to INT and adjust NULL DETECTOR for zero indication using ZERO control.
9) Turn detector SENSITIVITY control to minimum gain (ccw) and set GENERATOR switch to INT position.
10) Rotate MULTIPLIER knob slowly clockwise, one position at a time, until detector indication reverses polarity.
11) Reduce MAIN DECADE dial A setting (ccw) until detector reverses polarity, then rotate one position in opposite direction (cw).
12) Repeat step 11 for dials B thru D, increasing detector sensitivity as required.
13) Make final resistance bridge balance by adjusting dial E for a detector null.
14) Turn GENERATOR switch to OFF position.
15) Recheck null detector zero setting, adjusting ZERO control if necessary.
16) If zero setting has changed, turn GENERATOR switch to INT and rebalance the bridge by adjusting dials D and E as required.
17) The value of the unknown resistor is read from the MAIN DECADE dial times the MULTIPLIER setting.
18) Disconnect the unknown resistor and turn POWER switch to OFF position before leaving the Model 300 PVB.

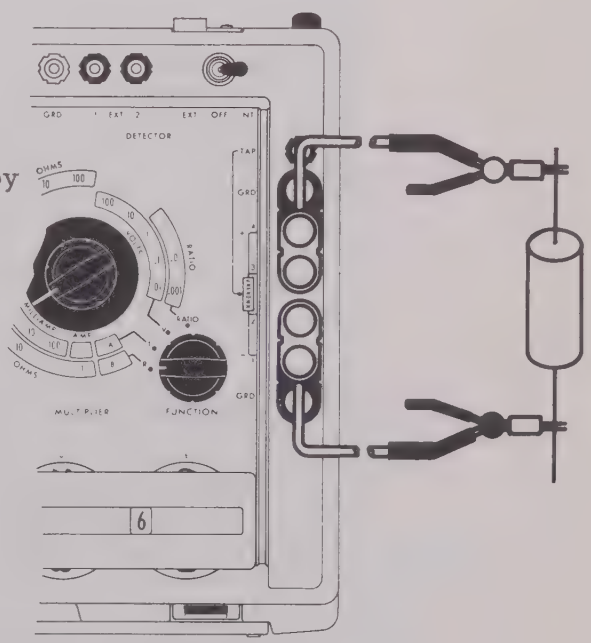


Figure 2.7 - Resistance Measurement

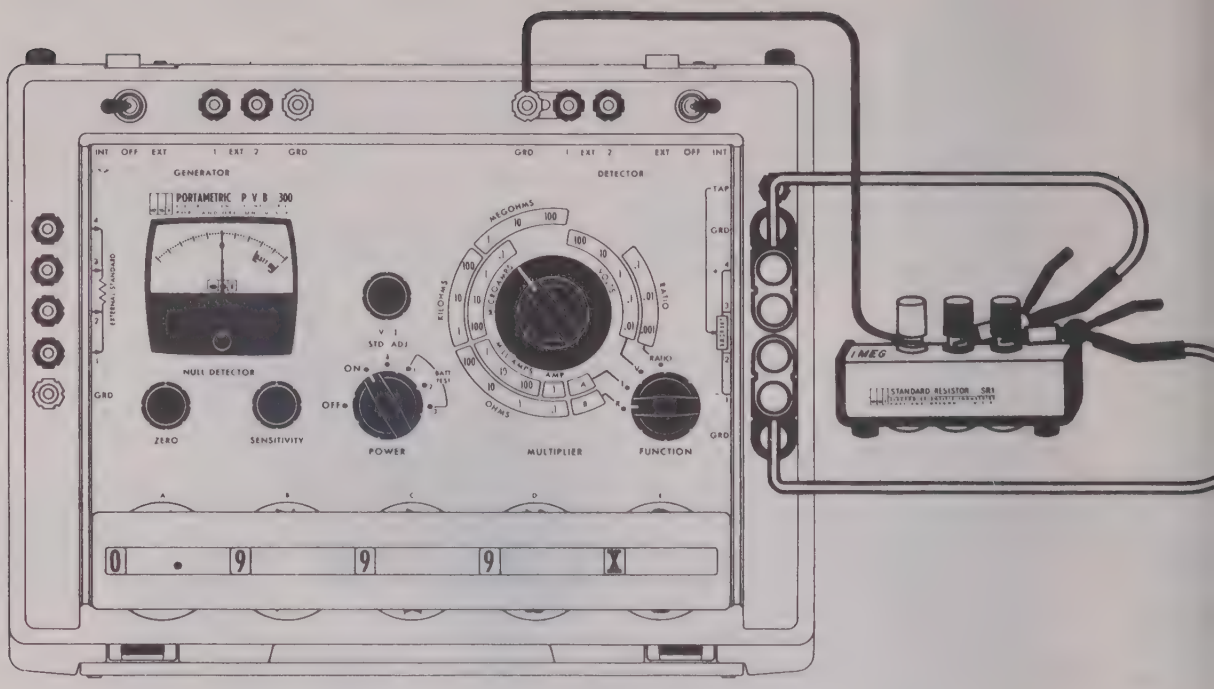


Figure 2.8 - Guarded Resistance Measurement

2.2.5 Ratio Measurement

1) Set FUNCTION selector to RATIO position.
2) Set MULTIPLIER selector to .1 RATIO.
3) Set GENERATOR switch to OFF and DETECTOR switch to OFF.
4) Set MAIN DECADE dials to 0.0000.
5) Turn POWER switch to ON position; allow 1 minute for stabilization.
6) Set SENSITIVITY control to maximum gain (cw).
7) Connect the unknown resistive voltage divider to the UNKNOWN terminals. If the measurement ratio is between 0 and 0.51, connect the divider high (1.0) end to terminals 3 and 4 and low (0) end to terminals 1 and 2. (If the ratio is between 0.51 and 1.0 reverse the divider high and low end connections.) The divider output terminal connects to the TAP terminal. See Figure 2.9.
8) Set unknown divider to desired output setting.
9) Set the DETECTOR switch to INT and rotate the ZERO control for NULL DETECTOR zero indication.
10) Turn detector SENSITIVITY control to minimum gain (ccw) and set GENERATOR switch to INT.
11) Increase MAIN DECADE dial A (cw) until detector reverses polarity, then rotate one position in opposite direction (ccw).
12) Repeat step 11 for dials B thru D increasing detector sensitivity as needed.
13) Make final null balance using decade dial E.
14) The value of the unknown ratio is read from the MAIN DECADE dial setting (S) times the MULTIPLIER setting (M). If the divider

high and low input leads were reversed because ratio was between 0.51 and 1.0, the ratio equals (10-S) times M.

15) Disconnect the unknown divider and turn the POWER switch to OFF before leaving the Model 300 PVB.

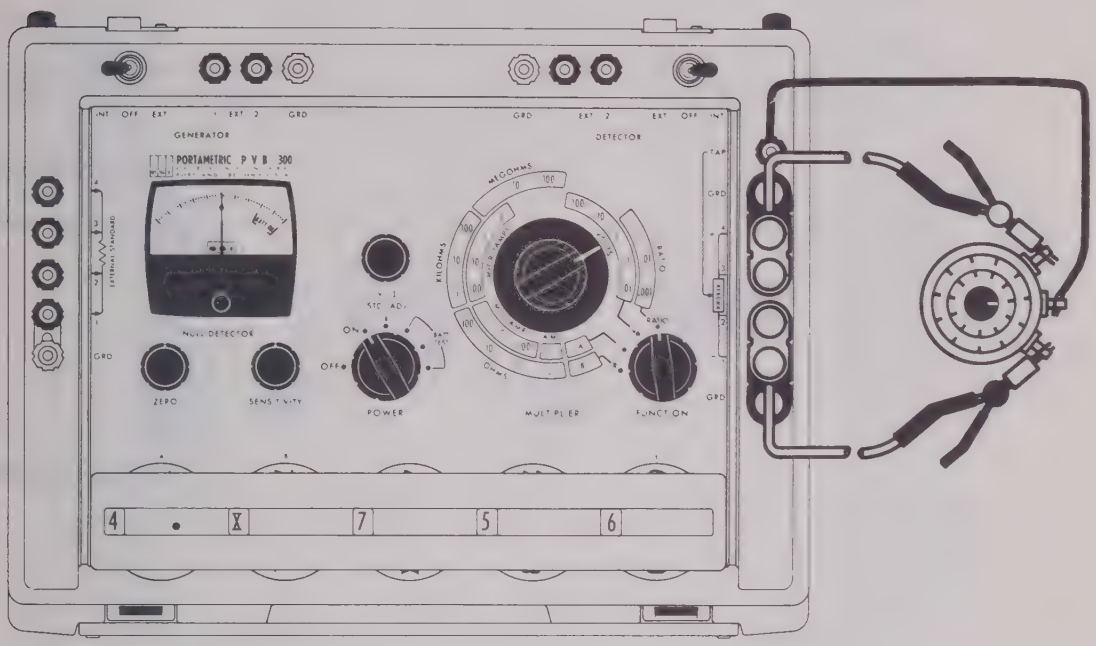


Figure 2.9 - Ratio Measurement

2.2.6 Comparison Bridge

1) Set FUNCTION switch to R.
2) Set MULTIPLIER switch to B.
3) Connect reference resistor to EXTERNAL STANDARD terminals; 2-, 3-, or 4-terminal connections may be made, as shown in Figures 2.10, 2.11, and 2.12.
4) Set GENERATOR and DETECTOR switches to OFF position.
5) Set MAIN DECADE dial to 1.0000.
6) Turn the POWER switch to ON position and allow one minute for stabilization.
7) Set SENSITIVITY control to maximum gain (cw).
8) Connect unknown resistor to the UNKNOWN terminals as shown in Figures 2.6, 2.7, and 2.8.
9) Set DETECTOR switch to INT position and adjust ZERO control to obtain a zero balance on NULL DETECTOR.
10) Set detector SENSITIVITY control so that NULL DETECTOR indicates something less than full scale. Set GENERATOR switch to INT.
11) Obtain zero balance on NULL DETECTOR with MAIN DECADE dials A thru E. If the unknown resistance is the same value as the reference resistor, the NULL DETECTOR will be close to a zero null with dials set at 1.0000. Make final null balance with the E dial.

12) The ratio of the value of the unknown resistor to the external standard resistor is read from the MAIN DECADE dial times the MULTIPLIER setting.
13) Disconnect unknown and standard resistors and turn POWER switch to OFF before leaving the Model 300 PVB.

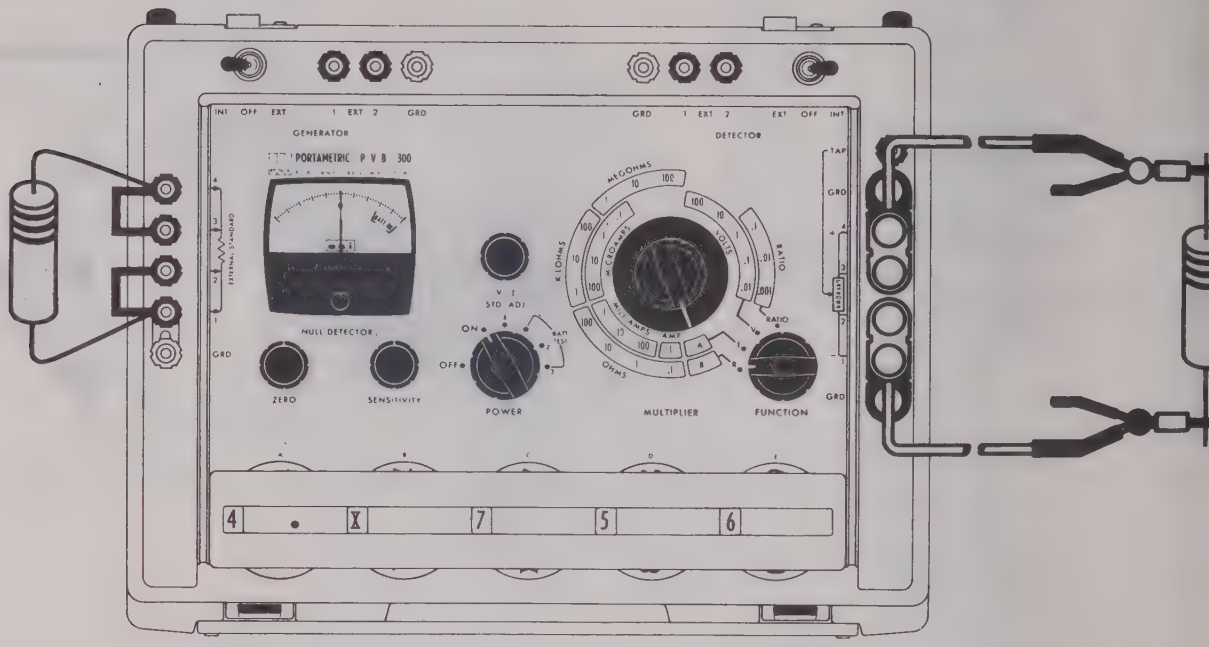


Figure 2.10 - Two-Terminal External Standard Connection

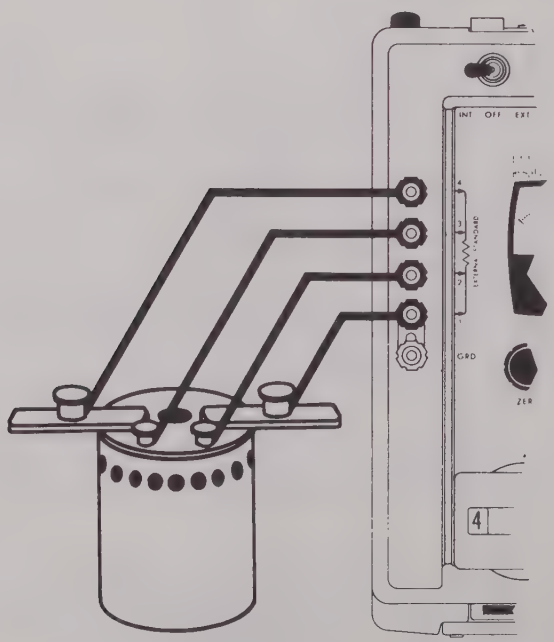


Figure 2.11 - Four-Terminal External Standard Connection

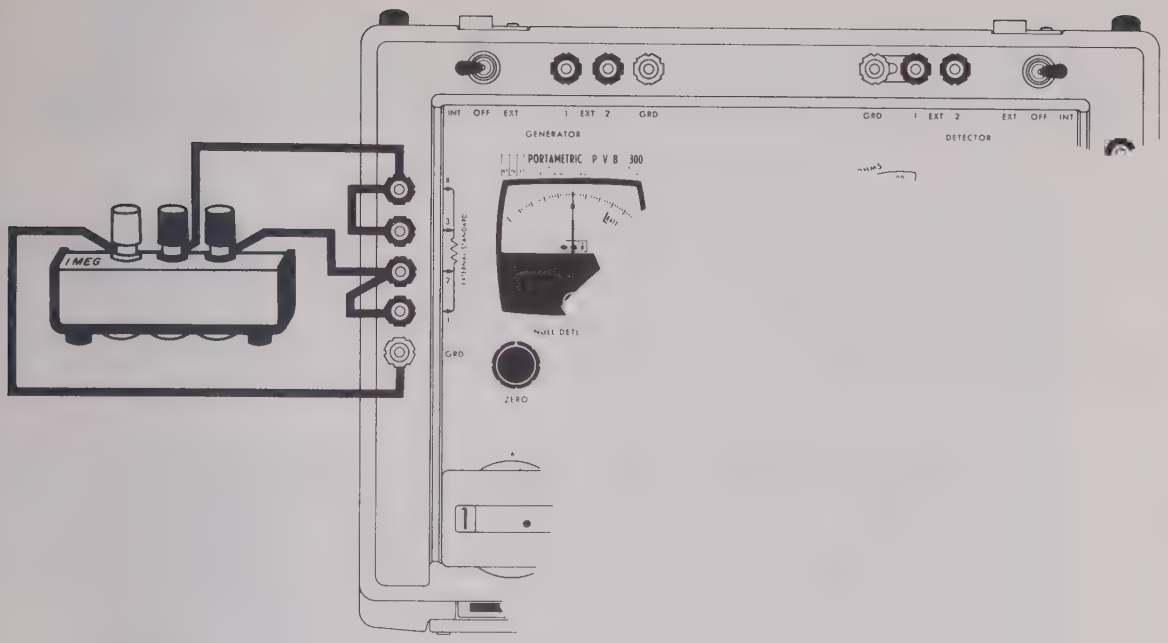


Figure 2.12 - Three-Terminal External Standard Connection

2.3 EXTENDED OPERATION

Extended operation of the Model 300 PVB is operation with external equipment to extend the range, sensitivity, or resolution of the instrument.

2.3.1 External Detector

Under some conditions it may be desirable to use a detector other than the one that is built into the instrument. The EXT DETECTOR terminals provide a connection for another detector. It is generally best to shield the external detector and the leads that connect it to the Model 300 PVB. No general rule can be given for shielding, but the following suggestions may be helpful.

Some detectors have both input lines separated from ground, and some detectors have one input line grounded to the detector chassis. If both input terminals are separated from ground, it is possible to connect the detector input terminals to EXT DETECTOR terminals 1 and 2, and connect the detector ground (usually the input cable shield) to the GRD terminal on the Model 300 PVB. If the external detector has one input terminal grounded, connect that line to EXT DETECTOR terminal 1, and connect a shorting link between terminal 1 and the GRD connector. Disconnect any shorting link that might be connected to any other GRD terminal. Failure to do so will probably result in an erroneous reading, and may damage an external detector that is not protected against overloads.

2.3.2 External Generator

It is possible to use an external generator to gain higher resolution or sensitivity when measuring very high or very low resistances with the Model 300 PVB.

For low resistances, the external generator is generally a battery or a low-resistance source of direct current.

CAUTION

Always power-limit the external generator to one watt unless MULTIPLIER switch is in A or B position and the generator voltage is less than 10 volts. Failure to limit power may damage precision resistors in the Model 300 PVB.

If MULTIPLIER switch is in A or B position, and an external standard is connected, limit the generator power to a value that will not harm the external standard.

The simplest way to limit the power of a source is to insert a resistor in series with it. Where the maximum power is one watt, the value of the resistor, R, is given by the following formula:

$$R = \frac{E^2}{4}$$, where E is the voltage of the power source.

Listed below are limiting-resistor values for commonly-used supply voltages. All resistors listed below can be ±20%, 5-watt resistors. If the nominal value listed is not available, use a higher value rather than a smaller.

LIMITING RESISTOR VALUES

SUPPLY VOLTAGE	RESISTOR VALUE (OHMS)
1	0.27
1.5	0.56
2	1.0
3	2.2
4	3.9
4.5	5.6
6	10
9	22
12	39
15	56
22.5	150
24	150
28	220
30	220
45	330
67.5	1.2k
90	2.2k
103.5	2.7k
120	3.9k
225	13k
300	22k
510	68k

2.3.3 External Current Shunt

The Model 300 PVB can be used with external current shunts to measure as large a current as desired. It is possible to use specially calibrated external shunts to cause the instrument to indicate any linear function of current. There are two methods of using external current shunts to measure current.

Method 1:

1) Connect current to be measured to current shunt.
2) Measure voltage between terminals of current shunt using procedure described in Paragraph 2.2.1.
3) Compute current in shunt from resistance of shunt and voltage across shunt. ($I = \frac{E}{R}$)

Method 2:

1) Set MULTIPLIER switch to A, set FUNCTION switch to I.
2) Connect shunt to EXTERNAL STANDARD terminals 2 and 3, and connect current to be measured to the external shunt or to the same terminals as the shunt. See Figure 2.13.

3) Measure current as described in Paragraph 2.2.3.

The current in amperes flowing through the shunt, I, is given by the following formula:

$$I = \frac{S}{10R_s}$$

where S is the setting of the main decade dials at null, and R_s is the resistance of the shunt in ohms. A few examples of shunt resistance and current multiplication factor are given in the following table. Multiply main decade setting at null by the current factor listed for the given shunt to find current through the shunt.

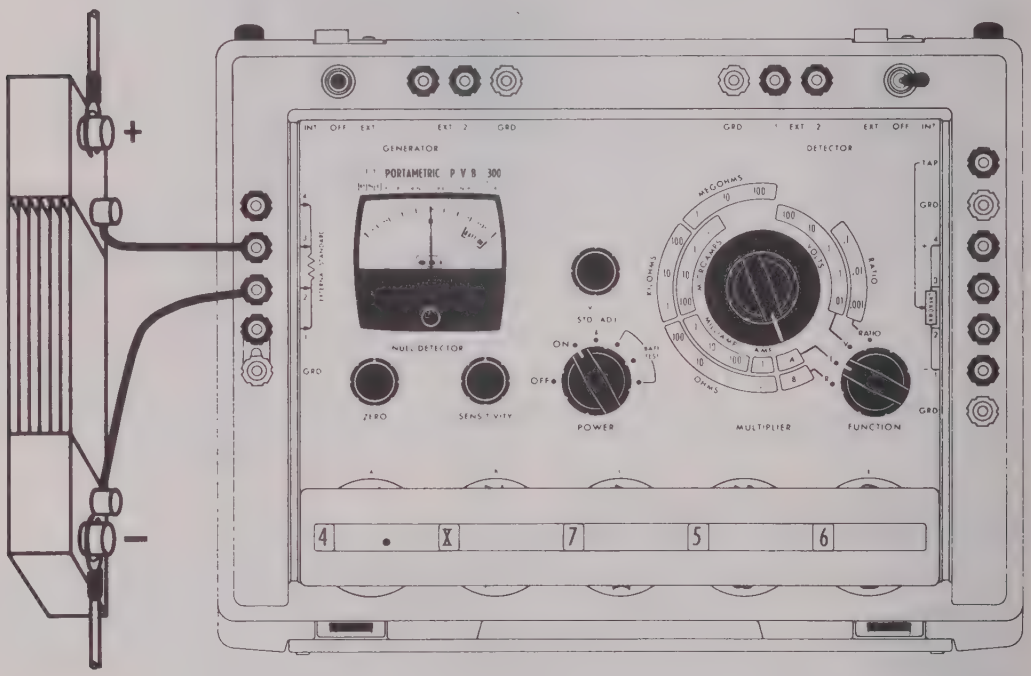


Figure 2.13 - External Current Shunt

SHUNT RESISTANCE (OHMS)	CURRENT FACTOR (AMPERES TIMES MAIN DECADE SETTING)
1.0	0.1
0.1	1.0
0.01	10
0.001	100
0.0001	1000
0.00001	10000

2.3.4 External Voltage Dropping Resistor

It is possible to use a voltage dropping resistor to extend the voltage range of the Model 300 PVB. The following procedure describes measurement of voltages between 500 and 5000 volts. Normal practice with voltages of this magnitude is to have one of the points between which voltage is to be measured at ground potential. However, it is not always desirable nor is it necessary that the ground point be at earth ground potential. This procedure assumes that one of the points between which voltage is to be measured is not more than 600 volts from earth ground potential, and that point will be called "signal ground" in the following procedure.

WARNING

These voltages are dangerous. Make sure that the instrument case is at the same ground potential as the operator. If possible, turn the voltage source off before making connections to it, turn it on while measuring, and turn if off again before disconnecting the instrument.

1) Set FUNCTION switch to V.
2) Set MULTIPLIER switch to 100 VOLTS.
3) Connect a wire or grounding strap from earth ground to one of the gold-plated GRD terminals.
4) Disconnect any shorting link that may be connected between GRD terminals and other terminals.
5) If the voltage to be measured is positive, connect signal ground to UNKNOWN terminal 1. If the voltage to be measured is negative, connect signal ground to UNKNOWN terminal 4. See Figure 2.14 for connections.

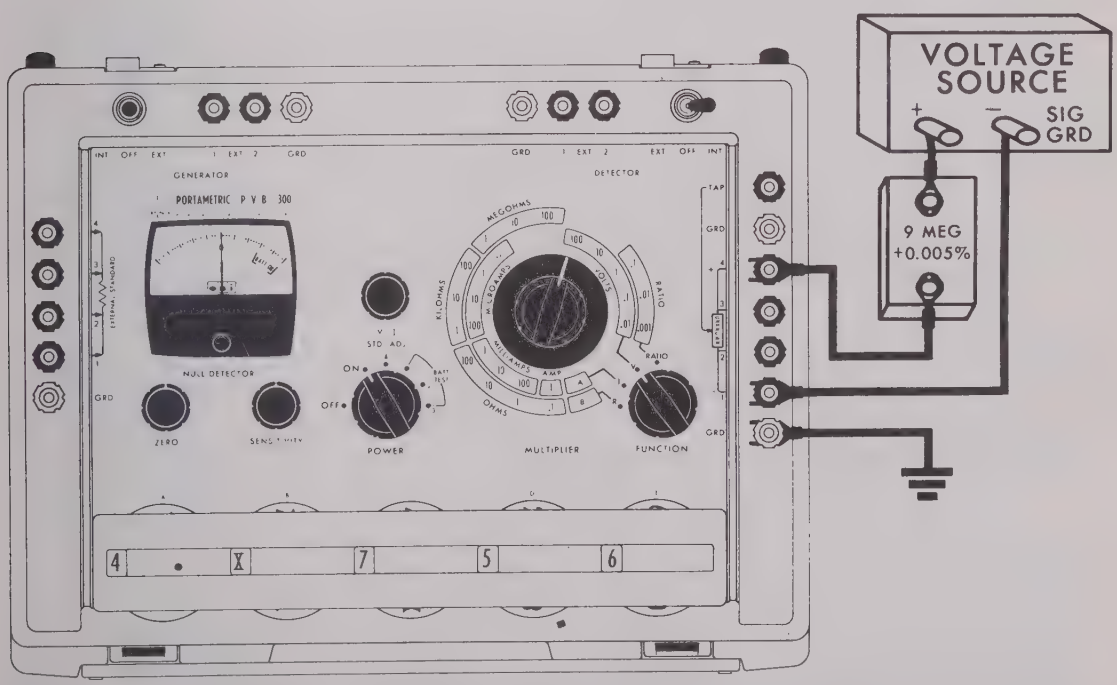


Figure 2.14 - High Voltage Measurement (Positive connection shown, refer to Paragraph 2.3.4 for negative connection.)

6) If the voltage to be measured is positive, connect a 9 megohm resistor between the voltage source and UNKNOWN terminal 4. If the voltage to be measured is negative, connect the resistor between the voltage source and UNKNOWN terminal 1. The accuracy of the voltage measurement will depend on the accuracy of the resistor.
7) Measure voltage as described in Paragraph 2.2.1, except that only the 100 and 10 VOLTS settings of the MULTIPLIER switch should be used. The voltage measured at null is 10 times the MULTIPLIER setting times the MAIN DECADE dial reading.

It is possible to use other values of external dropping resistor with the Model 300 PVB. The voltage measured by the Model 300 when the MULTIPLIER switch is in the 10 or 100 VOLTS position is the voltage dropped across the 1 megohm ±0.005% resistor inside the instrument. The following formula gives the voltage, E_t, across the dropping resistor and Model 300 PVB in series. E_p is the voltage measured by the Model 300, and R is the resistance of the dropping resistor in megohms:

$$E_t = E_p (R + 1)$$

2.4 AUXILIARY OPERATION

Auxiliary operation of the Model 300 PVB is operation that uses only part of the instrument. The Model 300 is made in such a way that it is possible to connect independently to the major subsystems of the instrument. The connections can be made from the external terminals. The major subsystems that can be operated in such a way are the null detector, the calibrated voltage supply, the main decade, and the internal resistance standards.

2.4.1 Null Detector Auxiliary Operation

The null detector can be operated with the FUNCTION switch in any position, but the connections differ for the various settings. Only one of the possible connections is described below. For other connections, refer to the schematic diagrams in the appendix.

1) Turn POWER switch to ON position, allow 1 minute for stabilization.
2) Set FUNCTION switch to RATIO.
3) Set DETECTOR switch to INT.
4) Set MULTIPLIER switch to .1 RATIO.
5) Make connections to EXT DETECTOR terminal 1 and UNKNOWN TAP terminal.

2.4.2 Main Decade Auxiliary Operation

The main decade may be used as a precision voltage divider. (Use as a precision decade resistor is possible but not recommended.) Note that the MULTIPLIER switch may be used in conjunction with the main decade to provide a precise fraction of an applied voltage.

1) Set FUNCTION switch to RATIO and MULTIPLIER switch to one of the RATIO positions as required.

CAUTION

Do not apply more than 300 volts to terminals in the following step. Do not short-circuit UNKNOWN terminal 3 to EXT DETECTOR terminal 1 while voltage is applied to the instrument. Either action could damage resistors in the main decade.

2) Connect voltage to be divided to UNKNOWN terminals 2 and 3; connect the zero reference voltage to UNKNOWN terminal 2.
3) The voltage divider output is between EXT DETECTOR terminal 1 and UNKNOWN terminal 2. The output voltage is the product of the input voltage times MULTIPLIER setting times MAIN DECADE dial settings.

2.4.3 Internal Resistance Standard Auxiliary Use

The internal standard resistors can be used as 2-, 3-, or 4-terminal resistance standards, and as a precision ten-to-one or hundred-to-one voltage divider.

To use the internal standard resistors as standards:

1) Turn POWER switch to OFF.
2) Set FUNCTION switch to I, and DETECTOR switch to OFF.
3) Set the MULTIPLIER to the desired resistance value between .1 OHMS and 1 MEGOHM. (Do not be concerned by the apparent inconsistency.)

Two-terminal resistances can be measured between UNKNOWN terminals 1 and 4.

If three-terminal measurements are required:

4) Disconnect any shorting link that may be between a GRD terminal and any other terminal.

The case of the instrument forms a shield for the resistor, and any of the GRD terminals can be used as the third terminal in a three-termina measurement.

For four-terminal measurements:

5) Set MAIN DECADE dials to 0.0000.
6) Set DETECTOR switch to EXT.
7) Connect resistance-measuring bridge to UNKNOWN terminals 1 and 4 and to EXT DETECTOR terminals 1 and 2. UNKNOWN terminal 1 and EXT DETECTOR terminal 1 connect to the same end of the resistor, and UNKNOWN terminal 4 and EXT DETECTOR terminal 2 connect to the same end of the resistor.

To use the internal standard resistors as a precision ten-to-one divider

1) Turn POWER switch to OFF.
2) Set FUNCTION switch to V.
3) Set MULTIPLIER switch to 10 VOLTS.
4) Set DETECTOR switch to EXT.
5) Connect voltage to be divided to UNKNOWN terminals 1 and 4. The input resistance is one megohm.
6) One tenth of the applied voltage can be measured between EXT DETECTOR terminal 2 and UNKNOWN terminal 1.

To use the internal standard resistors as a precision hundred-to-one divider, follow the above instructions except set MULTIPLIER switch to 100 VOLTS.

2.5 GENERATOR POWER

The generator used in the Model 300 PVB for resistance and ratio measurement is a two-level power-limited device. The schematic is shown in Figure 2.15.

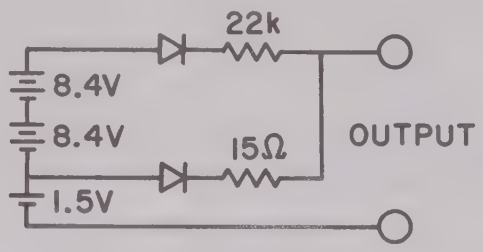


Figure 2.15 - Model 300 PVB Generator

Note that the 1.5-volt cell can furnish current through the 15-ohm resistor to the output only if the voltage dropped across the 22-kilohm resistor is equal to the voltage developed by the two 8.4-volt batteries; nominally 16.8 volts. If the output resistance is low enough for this to happen, the 1.5-volt cell furnishes a majority of the power; if the output resistance is too high for this to happen, the two 8.4-volt batteries furnish nearly all the power.

Since the different batteries furnish different voltages, the power-to-output-resistance curve is bimodal; see Figure 2.16.

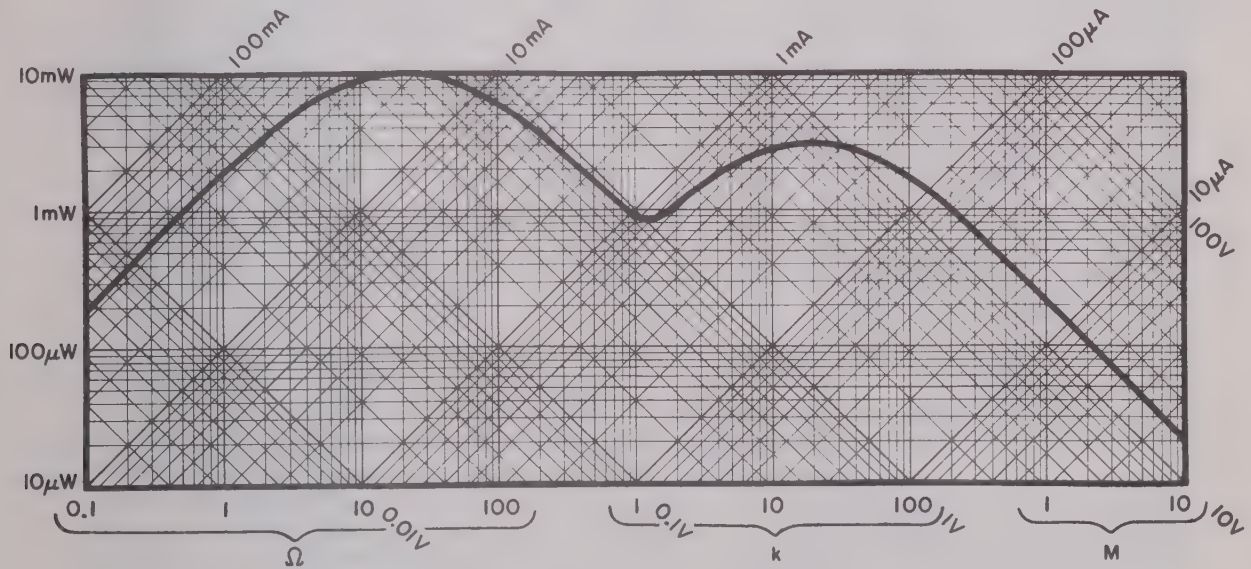


Figure 2.16 - Power, Resistance, Voltage and Current

The power developed across the unknown resistor connected to the Model 300 PVB depends on the decade dial setting, the range used, and the value of the unknown resistor. Figure 2.17 is a graph of the power developed across the unknown resistor when the Model 300 PVB Resistance Bridge is balanced; the curves for an unbalanced bridge are not very different from those shown. Each curve is for a different range of the instrument. The curves shown were plotted from the performance of an actual instrument, and should be considered typical.

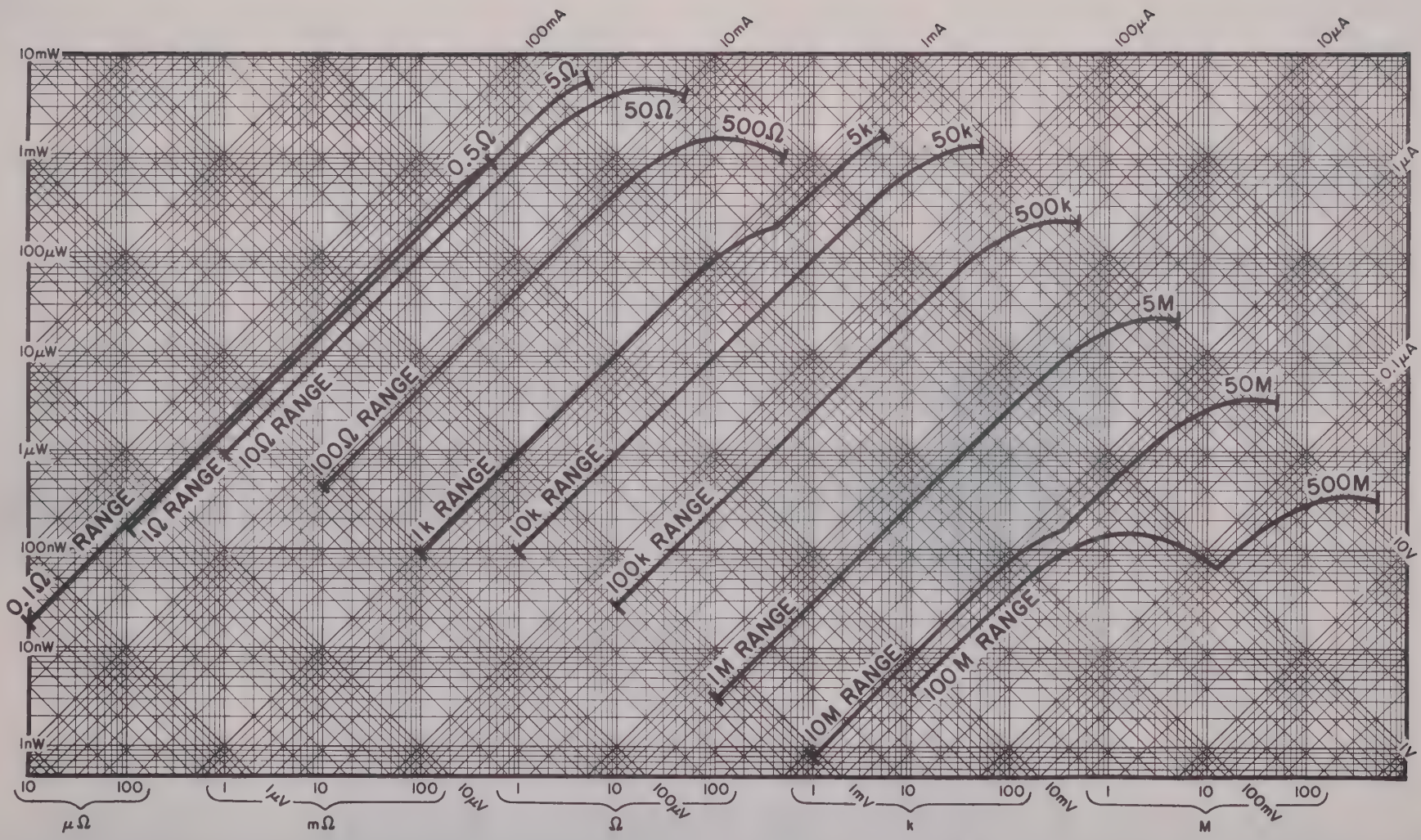


Figure 2.17 - Power Across Unknown Resistor

SECTION III

THEORY

3.1 GENERAL

The Model 300 PVB is a guarded Kelvin Bridge and a potentiometric voltmeter. A guarded Kelvin Bridge makes resistance measurements that are free of errors caused by series or shunt stray resistance. A potentiometric voltmeter makes voltage measurements that are free of errors caused by circuit loading.

3.1.1 The Kelvin Bridge

The Kelvin bridge in the Model 300 PVB is a four-terminal resistance-measuring system. The four-terminal technique uses either Kelvin Klips® or four separate connectors to eliminate errors caused by the resistance of the leads and the connectors. A complete discussion of the Kelvin bridge is contained in National Bureau of Standards Circular 470, "Precision Resistors and Their Measurements" by James L. Thomas. Another discussion of the Kelvin bridge and of guarded high-resistance measurements is contained in Design Ideas, Volume 1 Number 2, "Precision Resistance Measurement - Part I".

3.1.2 The Potentiometric Voltmeter

A potentiometric voltmeter can measure voltage with great accuracy because at null, it does not load the circuit from which it is measuring voltage. The Model 300 PVB is potentiometric on the three low ranges, and has a 1-megohm voltage divider that is used on the two higher ranges.

The potentiometric voltmeter is also used to measure current and ratio. Measurement of current is nothing more than measurement of voltage across a current shunt. Measurement of ratio is the comparison of the voltage drop across a known and an unknown divider.

3.2 SCHEMATIC DIAGRAMS

The following diagrams illustrate schematically the internal connections of the Model 300 PVB for each position of the FUNCTION switch.

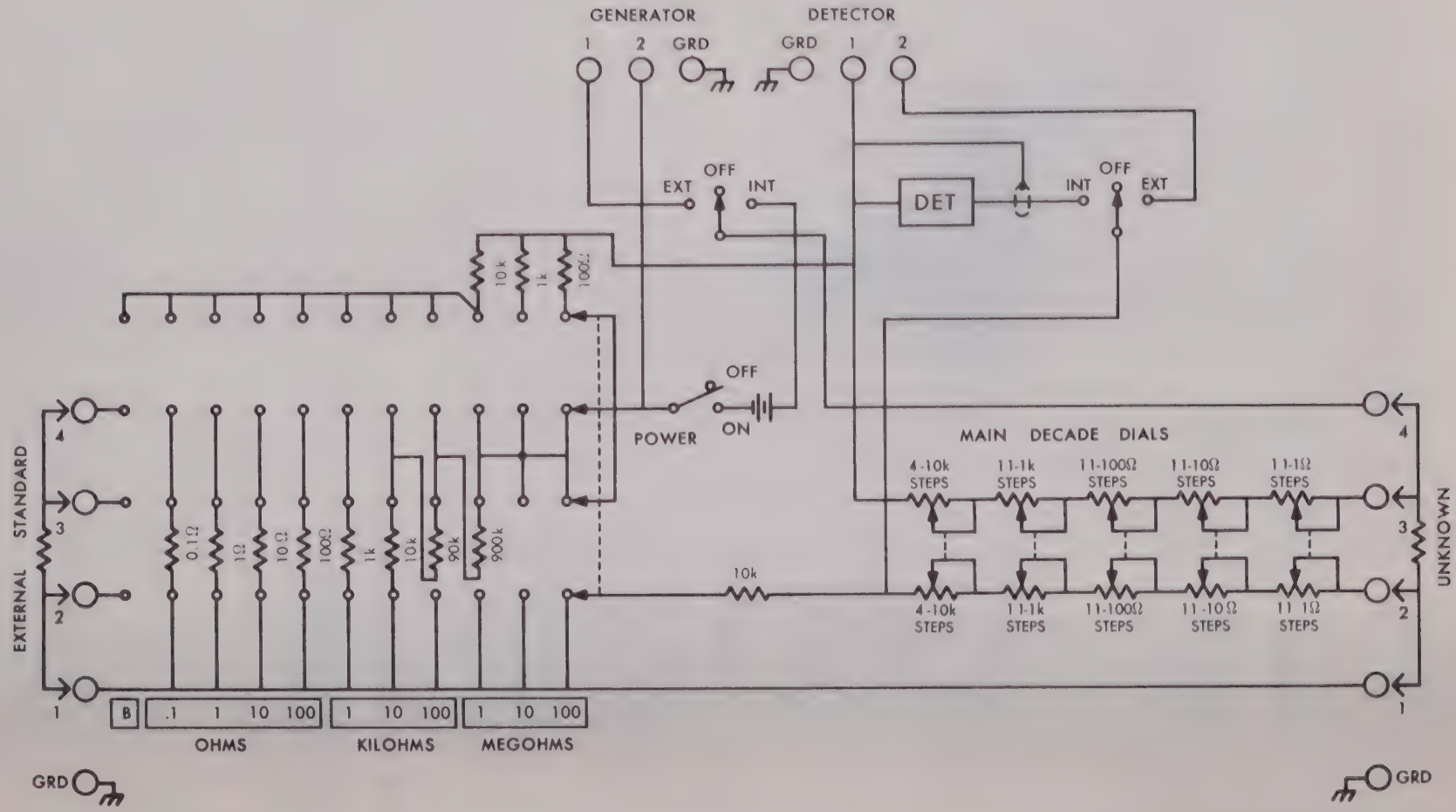


Figure 3.1 - Resistance Measuring Circuit

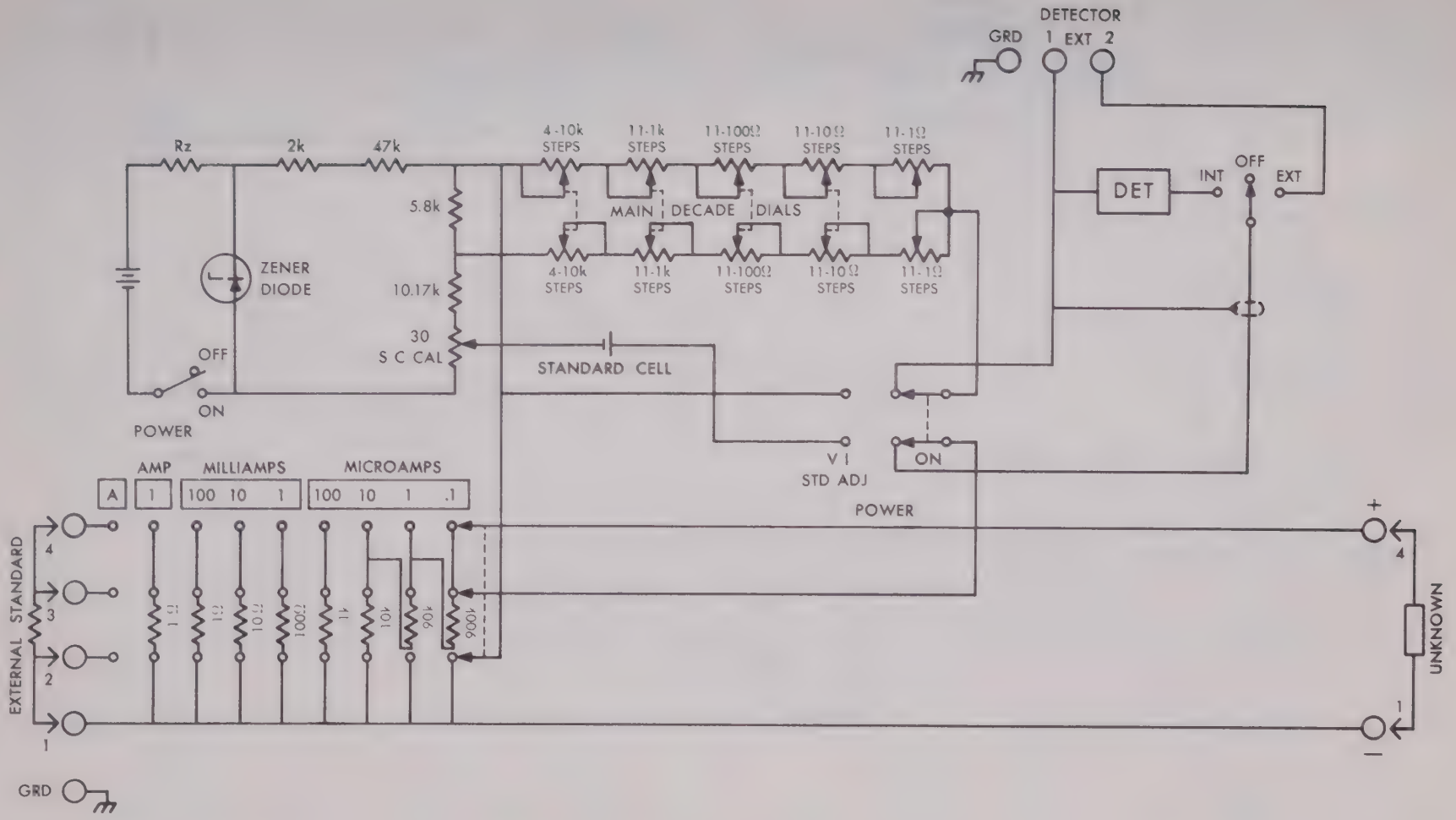


Figure 3.2 - Current Measuring Circuit

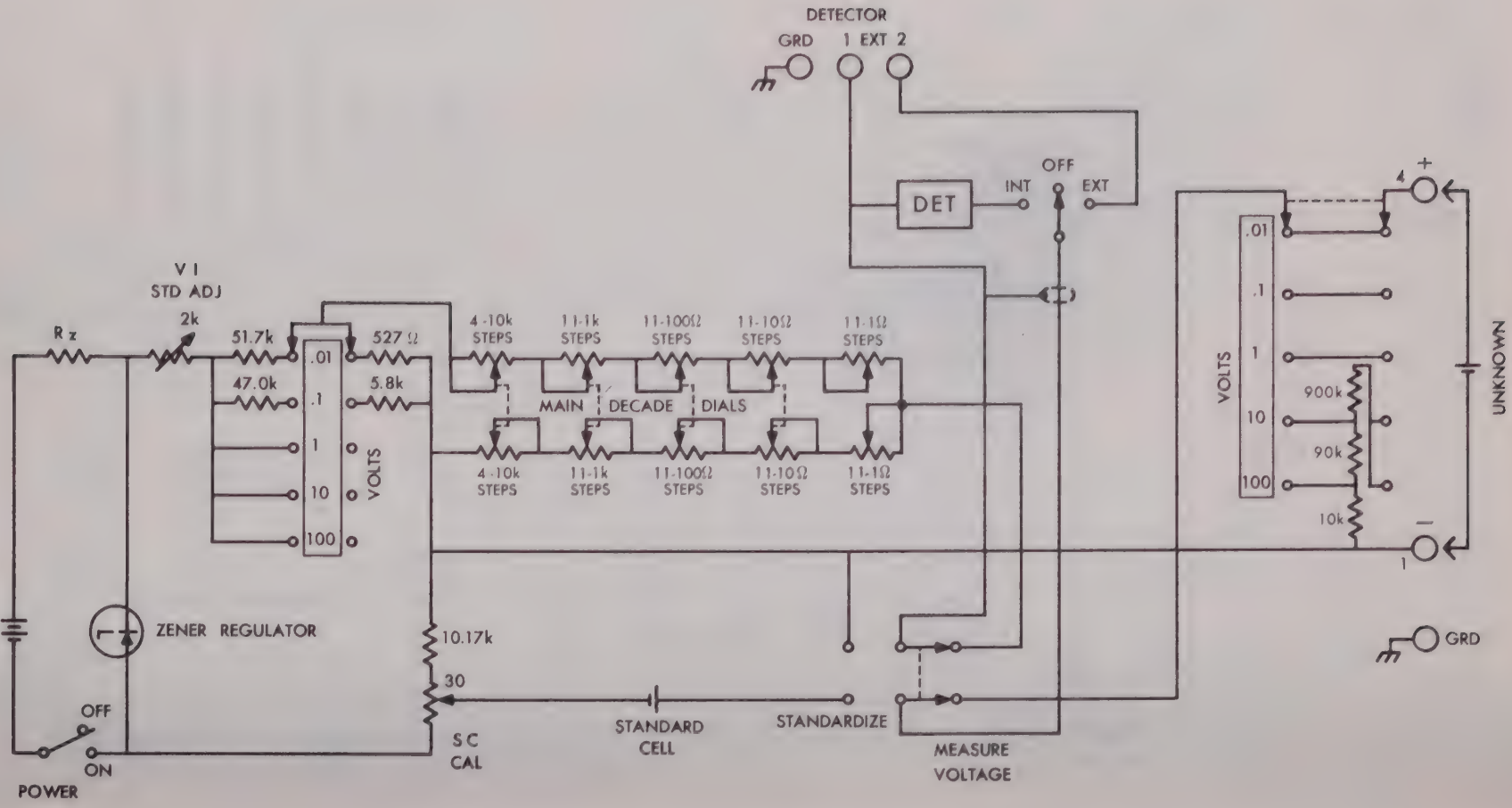


Figure 3.3 - Potentiometric Voltmeter Circuit

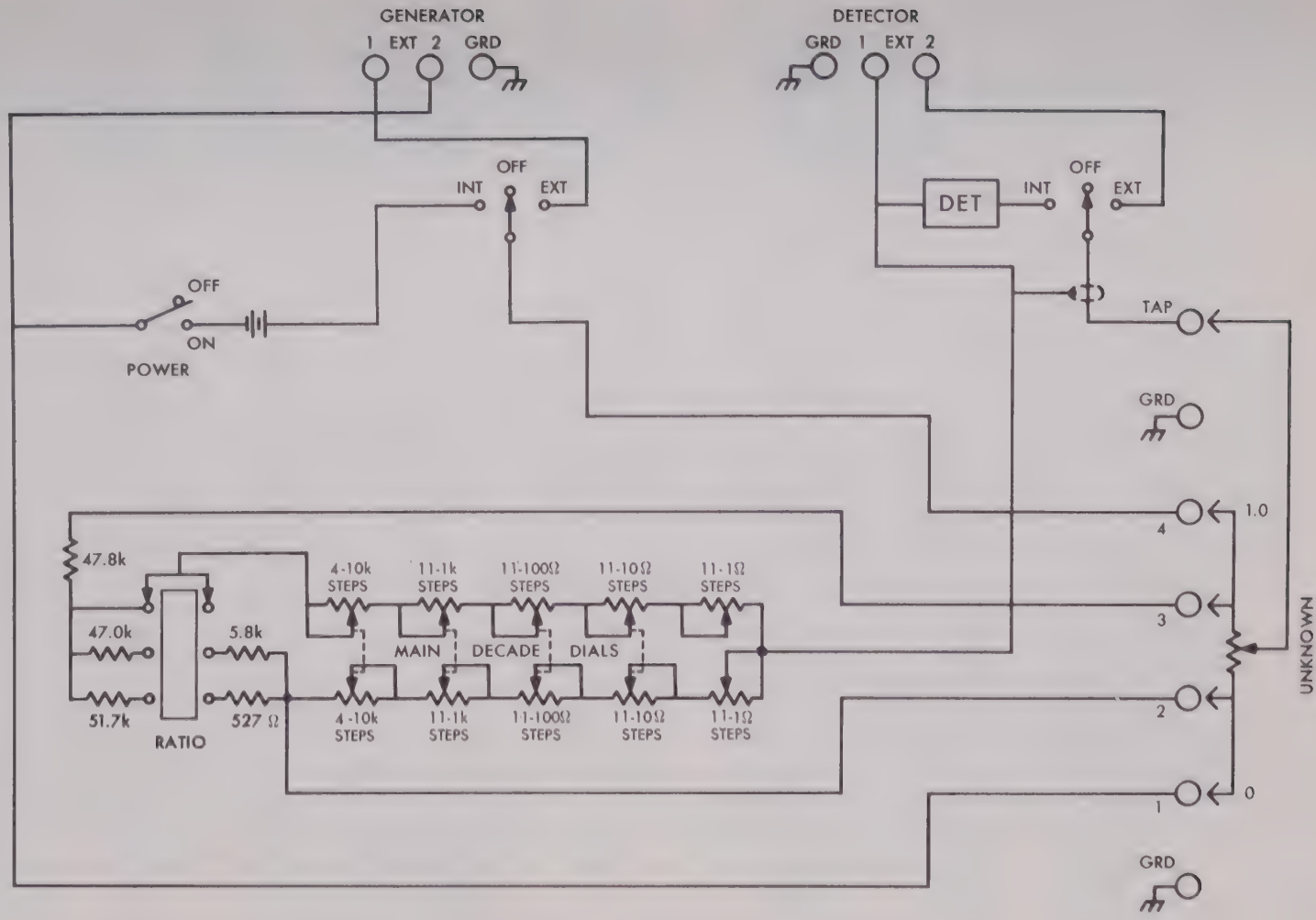


Figure 3.4 - Ratio Measuring Circuit

SECTION IV

MAINTENANCE

The Model 300 PVB will require very little maintenance unless it is subjected to extreme conditions of temperature, shock, or rough handling. The only periodic maintenance that will be necessary is checkout, battery replacement, and standard cell calibration. Checkout and standard cell calibration procedures should be performed every six months under normal conditions, every three months if extreme accuracy is required, or any time that there is reason to suspect that the instrument has been damaged.

The checkout procedure may be used as a validation procedure if validation is required. The checkout procedure is a guide to alignment and trouble-shooting. Do not make adjustments or attempt to repair unless the instrument does not meet the requirements set forth in the checkout procedure.

If the need for major repairs is apparent, it is recommended that the instrument be returned to the factory for service and repair. Our service department will be glad to furnish necessary repair information as well as replacement parts. Unauthorized repairs will invalidate the warranty on the equipment.

4.1 CHECKOUT AND STANDARD CELL CALIBRATION

The following table lists the equipment necessary to perform checkout and calibration procedures of the Model 300 PVB.

EQUIPMENT	USE	RECOMMENDED MODEL
Resistive Decade Voltage Divider with 100k input resistance	To check main decade linearity	ESI Model RV622 ESI Model RV722 or equivalent
Standard Resistors, 0.1, 1, 10, 100 ohms 1, 10, 100 kilohms 1 megohm	To check internal standard resistors	ESI Model SR-1 or equivalent
1.5-volt, 1-watt power supply (dry cell in series with 0.56-ohm resistor)	To improve resolution on low-resistance scale	No. 6 dry cell, 0.56-ohm, 5-watt resistor
Standard Cell	To calibrate Model 300 PVB internal standard cell	Epplab or Weston standard cell or equivalent
100-volt DC Supply	To improve resolution while checking RATIO range	100-volt to 120-volt supply with 1-watt power limiting (see Paragraph 2.3.2)

4.1.1 Mechanical Checks

1) Inspect the instrument for damage. Check binding posts, NULL DETECTOR meter, dials and switches, case hinges and latches, and carrying handle for damage.
2) Check the toggle switches. DETECTOR and GENERATOR switches should operate and remain in INT and EXT positions when they are so set.
3) Check ZERO, SENSITIVITY, and V, I STD ADJ controls. Controls should turn freely.
4) Check POWER, MULTIPLIER, and FUNCTION switches. Turn each of the switches fully counterclockwise. The pointers should be in the following positions: POWER switch at OFF position, MULTIPLIER switch at B and A, FUNCTION switch at R.
5) Check the main decade dials for alignment. The numbers on the dials should be centered in the windows. Turn main decade dial A counterclockwise; the number indicated should be 0. Turn each of the other main decade dials through a complete revolution. There should be no detent between X and 0 positions.
6) Check the binding posts. All binding post caps should be present, and should be removable. The gold-plated caps should be on the binding posts that are labeled GRD.

4.1.2 Battery Load Test

1) Set FUNCTION switch to RATIO position.
2) Set MULTIPLIER switch to .1 RATIO position.
3) Connect UNKNOWN terminals 1 and 4 together. Use Kelvin Klips®.
4) Turn POWER switch to BATT TEST positions 1, 2 and 3. If NULL DETECTOR pointer does not indicate a value between the BATT OK marks, replace the appropriate battery. Refer to Paragraph 2.1.2.

4.1.3 Null Detector Sensitivity Test

1) Set FUNCTION selector to V position.
2) Set MULTIPLIER selector to .01 VOLTS position.
3) Set DETECTOR switch to OFF.
4) Turn POWER switch to ON position; allow one minute for stabilization.
5) Set SENSITIVITY switch to maximum gain (cw).
6) Adjust ZERO control for NULL DETECTOR zero indication.
7) Turn POWER switch to V, I STD ADJ position.
8) Set DETECTOR switch to INT.
9) Turn STD ADJ control (10 turn) until NULL DETECTOR indicates a null.
10) Set POWER switch to ON position.
11) Connect UNKNOWN terminals 1 and 4 together. Use Kelvin Klips.
12) Set MAIN DECADE dials to 0.0300. The NULL DETECTOR should indicate full scale or more.

4.1.4 Stability Test

Stabilize the Model 300 PVB at a constant temperature for at least six hours before performing the stability test, and maintain the same temperature during the test. The temperature may be any temperature between 40°F and 140°F (between 5°C and 60°C), but the change of temperature should not be more than 2°F (1.1°C) per hour during the stabilization period.

Perform steps 1 through 10 of Paragraph 4.1.3. After 30 minutes, turn the POWER switch to V, I STD ADJ position. The NULL DETECTOR indication should be less than full scale.

4.1.5 Main Decade Linearity Test

1) Set FUNCTION selector to RATIO position.
2) Set MULTIPLIER selector to .1 RATIO.
3) Set GENERATOR switch to OFF and DETECTOR switch to OFF.
4) Set MAIN DECADE dials to 0.0000.
5) Turn POWER switch to ON position; allow one minute for stabilization.
6) Set SENSITIVITY control to maximum gain (cw).
7) Connect a standard resistive voltage divider to UNKNOWN terminals, the divider high (1.0) end to terminals 3 and 4, and low (0) end to terminals 1 and 2. Connect the divider output terminal to the TAP terminal.
8) Set standard divider to .000000.
9) Set DETECTOR switch to INT and rotate ZERO control for NULL DETECTOR zero indication.
10) Set GENERATOR switch to INT.
11) Adjust standard divider for NULL DETECTOR zero indication.
12) Set GENERATOR switch to OFF.
13) Increase the setting of the 0.1 dial of the standard voltage divider by one step, and increase the setting of the MAIN DECADE dial A by one step.
14) Set GENERATOR switch to INT. NULL DETECTOR should indicate zero within one switch step of MAIN DECADE dial E or 0.01% of MAIN DECADE dial reading, whichever is greater.
15) Repeat steps 12, 13 and 14 until either the MAIN DECADE dial or the standard divider dial has reached the limit of its travel.
16) Repeat steps 12 through 15 for each of MAIN DECADE dials and the appropriate standard voltage divider dial.
17) Set GENERATOR switch to OFF, MAIN DECADE dials to 0.0000, and MULTIPLIER selector to .01 RATIO. Repeat steps 8 through 11.
18) Set MAIN DECADE dials to 4.999X and increase setting of standard divider 0.01 dial five steps.
19) Set GENERATOR switch to INT. NULL DETECTOR should indicate zero within five switch steps of MAIN DECADE dial E.
20) Set GENERATOR switch to OFF, MAIN DECADE dials to 0.0000, and MULTIPLIER selector to .001 RATIO. Repeat steps 8 through 11.
21) Connect 100-volt DC supply to GENERATOR EXT terminals 1 and 2. Refer to Paragraph 2.3.2.

22) Set MAIN DECADE dials to 4.999X and increase setting of standard divider 0.001 dial five switch steps.
23) Set GENERATOR switch to EXT. NULL DETECTOR should indicate zero within five switch steps of MAIN DECADE dial E.
24) Disconnect 100-volt supply.

4.1.6 Internal Standard Resistor Test

Measure standard resistors of 0.1, 1, 10 and 100 ohms, 1, 10 and 100 kilohms and 1 megohm. Refer to Paragraph 2.2.4 for procedure. Make guarded connections to 100 kilohm and 1 megohm resistors. Use a size 6 dry cell or equivalent in series with a 0.56-ohm resistor as an external generator while measuring the 0.1 ohm resistor.

The resistance measured by the Model 300 PVB should be within two switch steps of MAIN DECADE dial E of the certified resistance of the standard resistors except the 0.1 ohm resistor, in which case the measured resistance would be within six switch steps of the certified resistance.

Measure the 1 megohm resistor with the MULTIPLIER selector on 10 and 100 megohm scales. The measured resistance should agree within one switch step of dial E of the certified resistance.

4.1.7 Standard Cell Calibration

The standard cell in the Model 300 PVB should be calibrated periodically; approximately every six months under normal conditions, more often if very high accuracy is desired. The instrument should be calibrated against a laboratory-type standard cell for which the voltage is accurately known.

1) Set FUNCTION selector to V.
2) Set MULTIPLIER selector to 1 VOLTS.
3) Set DETECTOR switch to OFF.
4) Remove battery compartment cover for access to STANDARD CELL ADJUST control.
5) Set MAIN DECADE dials to certified value of standard cell.
6) Turn POWER switch to ON and allow one minute for stabilization.
7) Set SENSITIVITY control for maximum gain (clockwise).
8) Adjust ZERO control for NULL DETECTOR zero indication.
9) Connect UNKNOWN terminals 1 and 4 to standard cell (Kelvin Klips may be used) with positive terminal of standard cell connected to UNKNOWN terminal 4.
10) Set DETECTOR switch to INT.
11) Adjust V, I STD ADJ control for NULL DETECTOR zero indication.
12) Turn POWER switch to V, I STD ADJ position and adjust STANDARD CELL ADJUST control for NULL DETECTOR zero indication.
13) Turn POWER switch to ON to make sure that NULL DETECTOR indicates zero with MAIN DECADE dials set to the certified value of the standard cell.
14) Replace battery compartment access door and disconnect instrument from standard cell.

4.2 TROUBLESHOOTING

If the Model 300 PVB does not function properly, observe all the symptoms before removing the instrument case. The validation procedure is useful for finding symptoms, especially Paragraphs 4.1.1, 4.1.2, 4.1.3, and 4.1.4, which are self-check procedures and require no external equipment.

4.2.1 Troubleshooting Table

The following table lists symptoms and probable causes of troubles. In almost all cases, only one probable cause listed in the table will fit all symptoms of a trouble; it is the most probable cause.

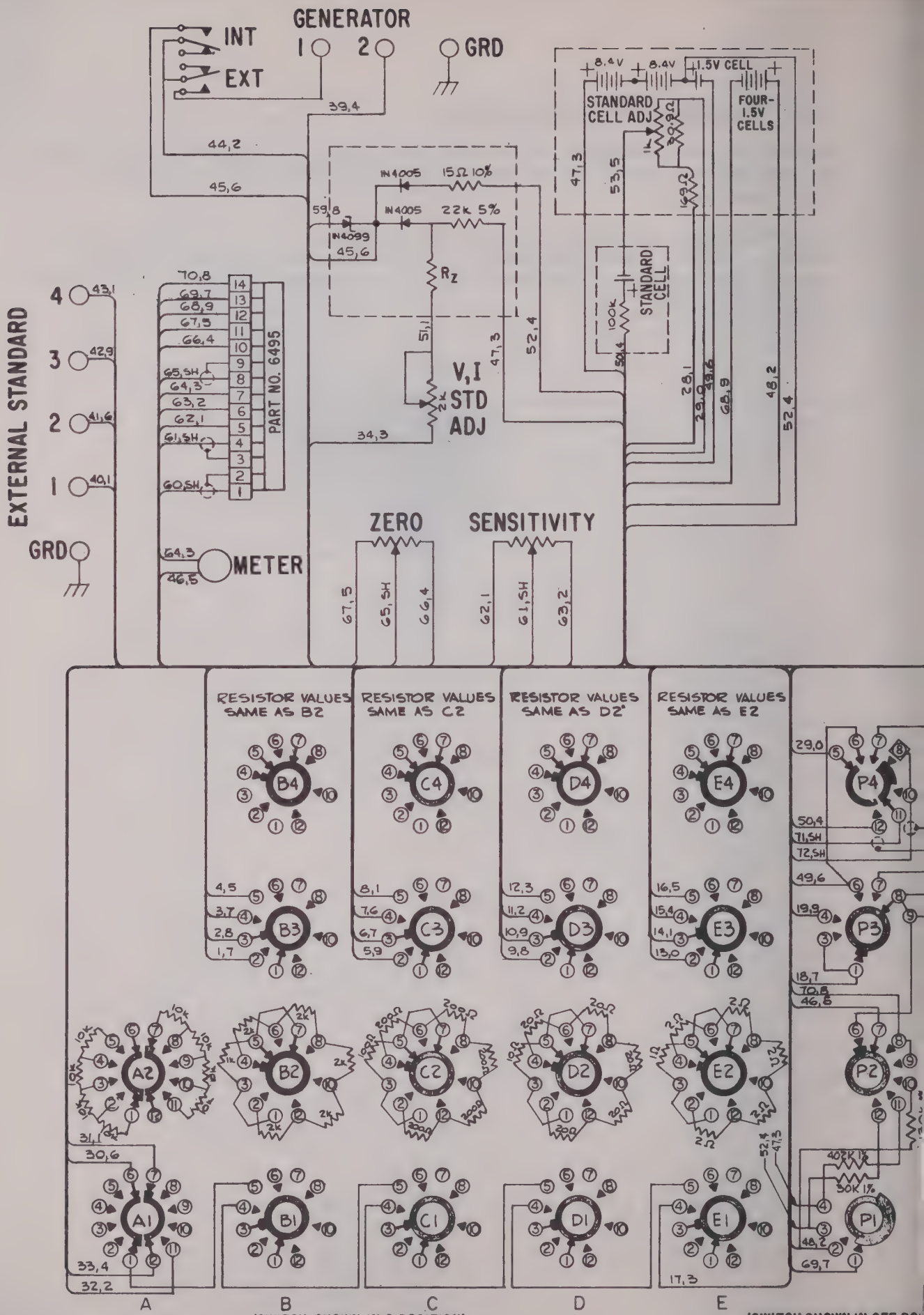
SYMPTOM	PROBABLE CAUSE
ZERO control will not adjust NULL DETECTOR pointer to zero	defective detector module defective detector meter defective ZERO control potentiometer
Detector sensitivity is too low (paragraph 4.1.3)	defective detector module defective detector meter defective SENSITIVITY control potentiometer
No NULL DETECTOR indication when POWER switch is in BATT TEST position	defective battery defective battery holder defective detector meter defective POWER switch
Reversed NULL DETECTOR indication when POWER switch is in BATT TEST position	battery or dry cell installed with reversed polarity
No NULL DETECTOR indication when measuring voltage or current or performing sensitivity test. (Be sure that FUNCTION and MULTIPLIER selectors are set properly, that POWER switch is in ON position, and that DETECTOR switch is in INT position.)	defective detector module defective meter defective DETECTOR switch defective POWER switch defective Kelvin Klip®

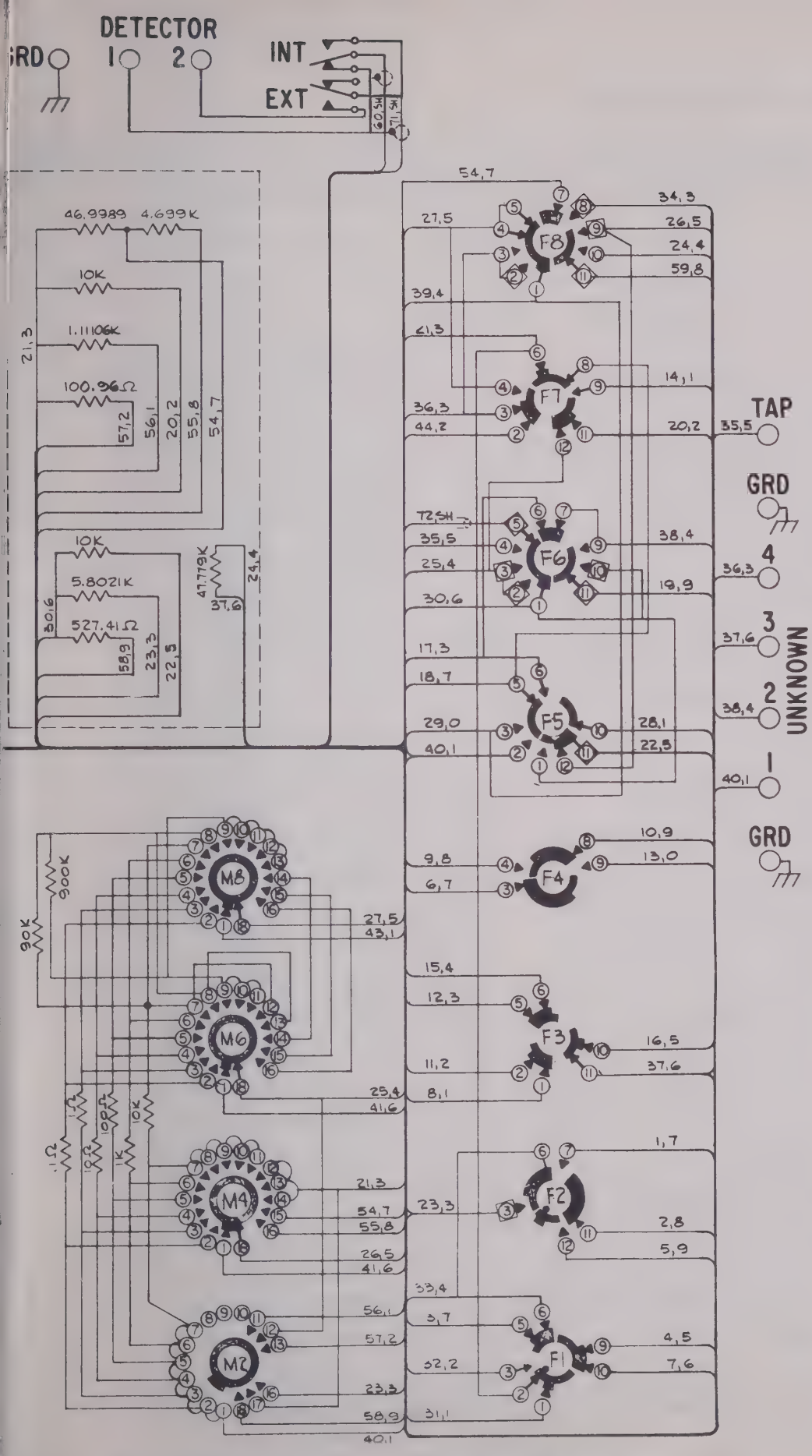
SYMPTOM	PROBABLE CAUSE
No external detector indication when measuring voltage or current with external detector connected (Paragraph 2.3.1)	
(1) Internal detector operates properly	(1) defective DETECTOR switch
(2) Internal detector does not operate properly	(2) defective POWER switch defective DETECTOR switch defective Kelvin Klip
No NULL DETECTOR indication on any range when GENERATOR switch is in INT position while measuring resistance or ratio; NULL DETECTOR operates properly when measuring voltage or current and during sensitivity test, Paragraph 4.1.3	defective GENERATOR switch defective internal generator circuit
Standardized voltage not stable (Paragraph 4.1.4)	defective zener diode in zener-regulated voltage supply
V, I STD ADJ control cannot be adjusted so that NULL DETECTOR indication is zero. (Be sure that POWER switch is in V, I, STD ADJ position.)	defective V, I STD ADJ control potentiometer defective standard cell defective standard cell adjustment potentiometer defective POWER switch defective zener diode in zener-regulated voltage supply
Standard cell adjustment control (in battery compartment) will not adjust NULL DETECTOR indication to zero during calibration (Paragraph 4.1.7)	defective standard cell defective standard cell adjustment potentiometer
Main decade indications are not linear (paragraph 4.1.5), or one main decade dial reading is manifestly false	defective main decade resistor defective main decade switch
NULL DETECTOR gives no indication or main decade indications are incorrect for certain settings of MULTIPLIER selector	defective MULTIPLIER selector switch defective range resistor

4.2.2 Removing the Instrument Case

Prepare a clean smooth area on which the instrument can be set face down. Be sure that there will be no pointed objects or projections under the instrument panel.

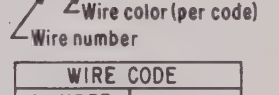
Place the instrument face-down on the prepared area. Remove four screws from the bottom of the instrument. It is not necessary to remove the battery cover or the rubber feet from the instrument. Lift the instrument case straight up.


GENERATOR
INT
EXT
1
2
GRD
39,4
44,2
45,6
8.4V
8.4V
1.5V CELL
STANDARD CELL ADJ
FOUR-1.5V CELLS
47,3
53,5
IN4005
15Ω 10%
IN4005
22K 5%
IN4099
59,8
45,6
R_Z
STANDARD CELL
100K
50,4
51,1
47,3
52,4
28,1
29,0
43,6
48,9
48,2
52,4
V,I STD ADJ
2K
34,3
EXTERNAL STANDARD
4
3
2
1
GRD
43,1
42,9
41,6
40,1
70,8
69,7
68,9
67,5
66,4
65,SH
64,3
63,2
62,1
61,SH
60,SH
14
13
12
11
10
9
8
7
6
5
4
3
2
1
PART NO. 6495
64,3
46,5
METER
ZERO
SENSITIVITY
67,5
65,SH
66,4
62,1
61,SH
63,2
RESISTOR VALUES SAME AS B2
RESISTOR VALUES SAME AS C2
RESISTOR VALUES SAME AS D2
RESISTOR VALUES SAME AS E2
B4
C4
D4
E4
4,5
3,7
2,8
1,7
B3
8,1
7,6
6,7
5,9
C3
12,3
11,2
10,9
9,8
D3
16,5
15,4
14,1
13,0
E3
A2
B2
C2
D2
E2
31,1
30,6
A1
B1
C1
D1
E1
33,4
32,2
17,3
29,0
P4
50,4
71,SH
72,SH
49,6
19,9
P3
18,7
70,8
46,8
P2
52,4
47,3
402K 1%
50K 1%
P1
48,2
69,7
A
B
C
D
E
(SWITCH SHOWN IN 0 POSITION)
(SWITCH SHOWN IN OFF PO
MAIN DECADE DIALS
POWER



NOTES:

1. Resistor R_z selected at factory
2. Wire designation:



WIRE CODE	
NUMBER	COLOR
0	BLACK
1	BROWN
2	RED
3	ORANGE
4	YELLOW
5	GREEN
6	BLUE
7	VIOLET
8	GRAY
9	WHITE
SH	SHIELD

3. Odd numbered switch decks (eg F1, P1) are front of deck, even numbered ones are rear of deck as seen from front
4. Front and rear switch clips are electrically connected except when insulated (eg ②)
5. Switch decks with same letter designation (eg F1, F3) have a common shaft coupling

4.3 REPLACEMENT PARTS

The following parts are available from the factory. It is recommended that parts not on this list be replaced or repaired at the factory. When ordering replacement parts, please include the following information:

Model and serial number of the instrument

ESI part number

Description of part

Description	ESI Part Number	Qty Used
Battery, 1.5 volt	5267	5
Battery, 8.4 volts, Mercury	6198	2
Capacitor, 150μf, 3 volt	1792	1
Detector Assembly[1]	6495	1
Meter	6542	1
Insulator, Meter Mounting	5101	6
Pot, 1k, Linear, ZERO	6577	1
Pot, 1k, Trim, Std Cell Cal	6579	1
Pot, 2k, 10 Turn	6547	1
Pot, Log, 100k, Sensitivity	6576	1
Regulator, Current	6593	1
Resistor Assy, 0.1Ω	6763	1
Resistor, 30.9Ω, 1/2W, 1%	6561	1
Resistor, 169Ω, 1/2W, 1%	6560	1
Resistor, 30k, 1/2W, 1%	2458	1
Resistor, 130k, 1/2W, 1%	1777	1
Resistor, 400k, 1/2W, 1%	6199	1
Resistor Switch Assy, 1st	9731	1
(consisting of)		
Disc, Resistor Support	18124	1
Resistor, 10k, ±0.005%	9721	8
Switch	6463	1
Resistor Switch Assy, 2nd	9732	1
(consisting of)		
Resistor, 2k, ±0.005%	9722	10
Resistor, 1k, ±0.005%	9723	2
Switch	6461	1

[1] Trade-in allowance for defective detector assembly.

Description	ESI Part Number	Qty Used
Resistor Switch Assy, 3rd	9733	1
(consisting of)		
Resistor, 200Ω, ±0.015%	9724	10
Resistor, 100Ω, ±0.015%	9725	2
Switch	6461	1
Resistor Switch Assy, 4th	9734	1
(consisting of)		
Resistor, 19.999Ω, ±0.02%	9726	10
Resistor, 9.999Ω, ±0.02%	9727	2
Switch	6461	1
Resistor Switch Assy, 5th	9735	1
(consisting of)		
Resistor, 1.999Ω, ±0.1%	9728	10
Resistor, .999Ω, ±0.1%	9744	2
Switch	6461	1
Resistor Switch Assy, Range	9736	1
(consisting of)		
Resistor, 1Ω, ±0.005%	9710	1
Resistor, 10Ω, ±0.005%	9712	1
Resistor, 100Ω, ±0.005%	9714	1
Resistor, 1k, ±0.005%	9716	1
Resistor, 10k, ±0.005%	9746	1
Resistor, 90k, ±0.005%	9718	1
Resistor, 0.9 Meg, ±0.005%	9730	1
Switch	6485	1
Std Cell Assy	6578	1
Switch, FUNCTION	6460	1
Switch, Lever Type	6599	2
Switch, Power	6481	1
Terminal Board Assy	6552	1
(consisting of)		
Terminal Board	6538	1
Resistor, 46.9989k, ±0.005%	9639	1
Resistor, 4.699k, ±0.005%	9649	1
Resistor, 10k, ±0.005%	9652	2

Description	ESI Part Number	Qty Used
Resistor, 1.11111k, ±0.005%	9737	1
Resistor, 101.005Ω, ±0.005%	9684	1
Resistor, 5.8023k, ±0.005%	9706	1
Resistor, 527.48Ω, ±0.005%	9708	1
Resistor, 47.779k, ±0.005%	9637	1
Access Door, Battery	6558	1
Label, Battery Replacement Instructions	6688	1
Battery Clip, Keystone #62	6565	2
Battery Tube, "C" Cell, Mylar	6842	1
Battery Tube "D" Cell, Mylar	6840	1
Battery Tray Assy	6555	1
Binding Post	1393	18
Cap, Binding Post, Insulated	1170	13
Cap, Binding Post, Gold-Plated	1172	5
Case, Instrument	6574	1
Catch, Female, Lid	6686	2
Dial, 0-4	6464	1
Dial, 0-X	6465	4
Gasket, Lid Seal	6794	2
Handle	6557	1
Bracket, Handle	6760	1
Pin, Handle	6570	2
Spring, Handle	6496	2
Retaining Ring, Handle	2357	2
Knob Assy, with Metal Skirt	6536	1
Knob, Large, Bar, Filled	1266	2
Knob, Small, Round, Filled	1268	2
Knob, Small, Round, Unfilled	1255	1
Lead Set, KELVIN KLIP[2]	6843	1
KELVIN KILP - set with Spade Lugs[2]	8306	1 pr
KELVIN KLIP - set with Shielded Plug Connectors[2]	9277	1 pr
Shield (used with Part No. 9277)	9321	2
Grounding Plug (used with Part No. 9277)	9333	2

[2] KELVIN KLIP sets are matched pairs. Some instruments are furnished with spade lug sets, some with shielded plug sets, and some with combined shielded plugs.

Description	ESI Part Number	Qty Used
KELVIN KLIP[2] set with combined Shielded Plug	6843	1
Lid	6479	1
Instruction, Lid	6586	1
Mask, Dial	6797	1
Shoulder Washer, Insulated, Binding Post	8823	13
Washer, Shoulder	3314	4

[2] KELVIN KLIP sets are matched pairs. Some instruments are furnished with spade lug sets, some with shielded plug sets, and some with combined shielded plugs.

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BATTERIES AND TUBES WHICH HAVE GIVEN NORMAL SERVICE ARE EXCEPTED.

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